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# MÉTODO SISTÊMICO PARA O DESENVOLVIMENTO E AVALIAÇÃO DE EMBALAGENS AMBIENTALMENTE SUSTENTÁVEIS

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# Método sistêmico para o desenvolvimento e avaliação de embalagens ambientalmente sustentáveis

Tese submetida ao Programa de Pós-Graduação em Engenharia de Produção da Universidade Federal do Rio Grande do Sul como requisito parcial à obtenção do título de Doutor em Engenharia, na área de concentração em Sistemas de Produção.

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Esta tese foi julgada adequada para a obtenção do título de Doutor em Engenharia e aprovada em sua forma final pelo Orientador e pela Banca Examinadora designada pelo Programa de Pós-Graduação em Engenharia de Produção da Universidade Federal do Rio Grande do Sul.

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*“Se olharmos para o mundo apenas através de uma pequena porta, sua perspectiva estreita, perderemos muitas coisas. Contudo, se tivermos uma perspectiva ampla, vasta, consciente e com empatia, teremos uma mente clara e seremos pessoas genuinamente inteligentes”.*

*Kyabgon Phakchok Rinpoche*

**RESUMO**

A embalagem é um importante componente do lixo produzido no planeta, é a parte visível, possui forma definida e comunica-se com o mundo. Em tempos de isolamento social em decorrência da pandemia COVID 19, o volume de embalagens aumentou, acompanhando o crescimento dos pedidos online de bens de consumo ou alimentos prontos. A importância de se estudar a relação entre sustentabilidade e embalagem é indiscutível e se encontra intensivamente pesquisada na literatura, porém dispersa em diversas áreas de conhecimento. No intuito de contribuir com este tema, O objetivo desta tese é propor um método para projetar embalagens, integrando os requisitos de sistemas e da sustentabilidade e a verificação do seu cumprimento ao longo do ciclo de vida. Para o desenvolvimento deste estudo foi utilizado o método *Design Science Research* e empregado um conjunto de técnicas como a revisão sistemática de literatura, a análise de conteúdo, a pesquisa bibliográfica e a pesquisa qualitativa. Esta tese está organizada em cinco capítulos, três dos quais contemplam artigos. O primeiro artigo apresenta uma revisão sistemática de literatura e tem por objetivo reunir informações sobre embalagens no contexto da sustentabilidade e, por meio de uma visão sistêmica do conteúdo, identificar oportunidades e definir diretrizes para o design de embalagens. O segundo artigo propõe um corpo de conhecimento, denominado Radar da Embalagem, que considera o arcabouço teórico próprio de cada etapa do ciclo de vida da embalagem e oferece uma perspectiva ao mesmo tempo simples e sistêmica, contribuindo como norteadora para o projeto de embalagens sustentáveis. O terceiro artigo propõe um método sistêmico para desenvolver uma embalagem sustentável ao longo do ciclo de vida. Sob o ponto de vista prático, o Radar da Embalagem se converteu em parte integrante do método. As etapas de projeto briefing, planejamento, desenho, implementação e validação foram organizados de modo circular, trazendo de modo intuitivo a necessidade de atenção às fases do ciclo de vida da embalagem, durante o projeto. Procedimentos, ferramentas, listas de verificação foram incorporadas a cada fase, visando apoiar o projetista. O ponto de partida lógico são as fases do pós-uso da embalagem e da extração da matéria-prima, etapas importantes para alcançar uma visão sustentável desde o início do projeto. Propõem-se a avaliação do atendimento à sustentabilidade durante todo o desenvolvimento do projeto, buscando garantir a redução do impacto ambiental em todo o processo. Por fim, o método foi testado em um caso real de uma embalagem projetada para acondicionar fatias de pizza comercializadas em estádios de futebol.

Palavras-chave: Embalagem. Metodologia projetual. Sistemas complexos. Sustentabilidade.

**ABSTRACT**

Packaging is an important component of the waste produced on the planet, it is the visible part, has a defined shape and communicates with the world. In times of social isolation due to the COVID 19 pandemic, the volume of packaging has increased, following the growth of online orders for consumer goods or ready-to-eat foods. The importance of studying the relationship between sustainability and packaging is unquestionable and has been intensively researched in the literature, but dispersed in different areas of knowledge. To contribute to this theme, the objective of this thesis is to propose a method for designing packaging, integrating systems and sustainability requirements, and verifying its performance throughout the life cycle. For the development of this study, the Design Science Research method was used and a set of techniques of systematic literature review, content analysis, bibliographic research and qualitative research were used. This thesis is organized into five chapters, three of which include articles. The first article presents a systematic literature review and aims to gather information on packaging in the context of sustainability and, through a systemic view of the content, identify opportunities and define guidelines for packaging design. The second article proposes a body of knowledge, Radar da Packaging, which considers the theoretical framework of each stage of the packaging life cycle, which offers a perspective that is both simple and systemic and that serves as a guideline for the design of sustainable packaging. The third article proposes a systemic method to develop sustainable packaging throughout the life cycle. From a practical point of view, the Packaging Radar has become an integral part of the method. The briefing, planning, design, implementation, and validation project stages were organized in a circular mode, intuitively bringing the need to pay attention to the packaging life cycle phases during the project. Procedures, tools, checklists were incorporated into each phase to support the designer. The logical starting point is the post-use of packaging and raw material extraction phases, important steps to achieve a sustainable vision from the beginning of the project. It is proposed to evaluate compliance with sustainability throughout the development of the project, seeking to ensure the reduction of environmental impact throughout the process. Finally, the method was tested in a real case of a package projected to contain pizza slices sold in football stadiums.

Key words: Packaging. Design Methodology. Complex systems. Sustainability.

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# 1. INTRODUÇÃO

O projeto no Design é uma atividade que ocorre no tempo e que utiliza técnicas para gerar e avaliar ideias que venham a solucionar algum problema que necessite de uma abordagem criativa. Se não é uma atividade temporal e/ou não utiliza técnicas, conhecimento sistematizado, então não é um projeto (LINDEN; MARTINS, 2012). No caso das embalagens, ao projetar, o profissional responsável deve levar em consideração que existe uma tênue divisão entre projeto de produto e o projeto gráfico, pois, em uma embalagem ótima, esses dois aspectos se complementam (NEGRÃO; CAMARGO, 2008).

A linguagem visual da embalagem consiste em um vocabulário próprio que deverá ser decifrado pelo designer e é exatamente por essa linguagem própria que a embalagem se diferencia de outras técnicas de design, ela contém a assinatura do produto e da empresa na forma da sua marca, tipografias, cores, fotografias, ilustrações, informações obrigatórias normativas e regulatórias, acabamentos e efeitos, uma linguagem própria e também deve seguir uma hierarquia de informações planejada para chamar atenção do seu público alvo (MESTRINER, 2002; NEGRÃO; CAMARGO, 2008). Segundo Roncarelli, (2010) para ser relevante, o design da embalagem deve sugerir o produto que contém ou o público ao qual ele se destina. Não tem que ser explícito ou óbvio, mas a ideia do design deve criar uma conexão com o consumidor, seja no plano lógico, ou no plano emocional.

Em relação ao design da parte formal da embalagem, é recomendado que a seleção da matéria-prima, como a embalagem será fabricada e o seu projeto estrutural sejam definidos antes da aplicação gráfica, pois estes elementos nortearão o projeto como um todo (STEWART, 2010). O conhecimento técnico do projetista neste sentido deve perpassar diferentes referenciais teóricos e áreas de conhecimento, pois envolve geometria, desenho técnico, conhecimento sobre materiais, sobre os processos de fabricação da embalagem disponíveis no mercado, além do conhecimento sobre os processos de envase, transporte, armazenagem e descarte. Segundo Fontoura (2011) o design é por natureza interdisciplinar, trata-se de uma área propicia para o trabalho conjunto com outras áreas de conhecimento. Uma das características de uma atividade de Design é o envolvimento de inúmeros conhecimentos de domínios distintos. O projetista busca se apropriar de conhecimentos específicos sobre o projeto a ser executado.

Políticas governamentais adotadas em determinadas épocas e nações estimularam o desenvolvimento do mercado consumidor, e as embalagens foram ganhando importância. A função primária, de contenção e proteção, foi sendo ampliada em consequência do autosserviço, típico das lojas. Percebeu-se que, pela substituição do contato humano que ocorria nas feiras e pequenas vendas, a embalagem foi assumindo um novo papel, o de comunicação (SASTRE, 2017). Qualidades como a resistência ao transporte e umidade, continuam essenciais, mas foram agregadas outras funções importantes, como a identificação do fabricante do produto embalado e o poder de sedução exercido sobre os consumidores (PEDRO CAVALCANTI, 2006). O que era um simples envoltório, se transformou em uma ferramenta de marketing (SASTRE, 2017).

Em contrapartida, segundo (LU et al., 2020) o excesso de embalagens desafia o desenvolvimento sustentável da nossa sociedade. O que fazer com os resíduos gerados pelas embalagens no planeta, quais as soluções encontradas para minimizar os impactos ambientais? A transição da economia linear dominante para um modelo baseado na circularidade por intenção e design pode construir uma nova base essencial para a economia de mercado e utilização de embalagens (CASAREJOS et al., 2018). A maioria dos métodos de fabricação são lineares, a empresa extrai alguns materiais, produz alguma coisa e vende ao consumidor, que a descarta quando ela não mais se presta à sua finalidade original (WEETMAN, 2019). O conceito de economia circular torna-se relevante na busca de soluções para evitar ou minimizar o problema do resíduo gerado pelas embalagens. O conceito de economia circular, segundo (WEETMAN, 2019), diz que ela é uma economia verdadeiramente sustentável, que funciona sem resíduos, poupa recursos e atua em sinergia com a biosfera. Em vez de tratar as emissões, os subprodutos e os bens danificados ou indesejados como "resíduos" ou "lixo", esses itens, na economia circular, tornam-se matéria-prima e insumos para um novo ciclo de produção.

Diante do contexto que se estabelece na atualidade, Sastre et al. (2020) argumentam que a definição conceitual de embalagens deve ser ampliada:

> *"(...) as embalagens são recipientes ou invólucros, que têm como funções primárias conter, proteger e transportar mercadorias, e podem ser classificadas como complexas e sistêmicas, abrangendo interações previsíveis e/ou inesperadas entre suas partes e processos, devendo, portanto, ser consideradas sob a perspectiva de todo o seu ciclo de vida* (SASTRE et al., 2020).

Por esta razão, a embalagem deve ser desenvolvida sempre que possível com matérias-primas de fontes renováveis, deve ser mantida em uso pelo maior tempo e ao final da vida, contribuir com a regeneração de sistemas naturais. O grande desafio encontrado pelos projetistas de embalagens é conseguir fazer com que ela cumpra todas as suas funções de maneira satisfatória, atendendo a cadeia de *stakeholders* envolvidos e interligados, contemplando a interação da embalagem com o produto, seu usuário, a indústria convertedora e de envase, com foco em uma solução sustentável que não agrida o meio ambiente.

O desenvolvimento sustentável é, em essência, o que atende às necessidades e aspirações da geração atual sem destruir os recursos necessários para as gerações futuras atenderem às suas necessidades (HOLDGATE, 1987). Contextualizando, o conceito de embalagem sustentável está diretamente relacionado a minimização do impacto ambiental (MANZINI, 2005).

Além disso, o conceito de 'embalagem sustentável', adaptado de Abdul Khalil et al. (2016); Besier (2015); Petjak; Naletina; Bilogrevic (2019) foi entendida como:

> *(...) é aquela projetada com materiais recicláveis, com avaliações de ciclo de vida que minimizem a pegada ecológica, o seu impacto social e ambiental. Deve atender aos critérios do mercado para seu desempenho funcional e social, dentro dos limites financeiros aceitos* (ABDUL KHALIL et al., 2016; BESIER, 2015; PETLJAK; NALETINA; BILOGREVIĆ, 2019).

A promoção da sustentabilidade em embalagens torna-se uma tarefa destinada a profissionais especializados na área que obrigatoriamente deve dar conta dos aspectos teóricos e práticos relacionados a embalagem. Observa-se que na prática existe uma certa dificuldade por parte dos pesquisadores e projetistas em adotar um olhar sistêmico nos projetos de embalagens. Assim, uma tarefa complexa é também aquela para a qual muitos fatores devem ser considerados para determinar o resultado de uma ação (BAR-YAM, 2003). Pode ser compreendida como um sistema composto de diversos elementos entrelaçados (MUNIZ; POSSAMAI, 2019). É composto de muitas partes que interagem de uma forma não simples (BARABASI, 2005). Neste sentido, a embalagem pode ser considerada como um sistema complexo, pois é projetada para atender exigências de diferentes stakeholders ao longo do seu ciclo de vida, e a interdependência e as relações entre as cadeias de eventos ao longo deste ciclo afetam o comportamento do todo. Uma simples mudança na aba de fechamento de uma embalagem pode ocasionar um problema na etapa de envase do produto ou na correta manipulação pelo usuário final, por exemplo.

Existem especialistas atuando em áreas especificas como o design gráfico ou a indústria gráfica produtora de embalagens, muitas vezes estes profissionais dominam as suas áreas, porém não atuam buscando uma solução integrada ao projeto ou não possuem conhecimento aprofundado sobre o tema, o que pode ocasionar problemas em alguma das etapas do seu ciclo de vida, como a destinação correta em seu pós-uso, por exemplo. Segundo (BAR-YAM, 2003) simplificar uma tarefa complexa ignorando a necessidade de respostas diferentes é o que leva a erros ou falhas que afetam o sucesso de todo o esforço, deixando-o como uma aposta com riscos cada vez maiores (BARABASI, 2005).

Em relação a integração da embalagem com o processo de desenvolvimento de produto, segundo Bucci; Forcellini (2007) a realidade mostrou que a maioria das empresas tem seu processo de desenvolvimento de produtos totalmente independente do processo de desenvolvimento de embalagem. Como resultado, eles enfrentam perdas de competitividade, aumento de custos e prazos de entrega mais longos. Além disso, também traz um desempenho ambiental desfavorável tanto para o produto quanto para a embalagem. As empresas têm focado suas preocupações no desempenho ambiental dos produtos. Assim, tanto o desenvolvimento de produtos quanto de embalagens tornou-se de grande importância, uma vez que seu desempenho ambiental é determinado principalmente durante o processo de desenvolvimento de produto (BUCCI; FORCELLINI, 2007).

Observa-se que dentre os autores que enfatizaram método para o projeto da embalagem estudados ao longo desta tese, adotam estratégias para a sustentabilidade ambiental da embalagem, mas abrangendo frações do ciclo de vida, não o ciclo como um todo. Nenhum destes enfatizou o uso de métricas de avaliação. Por outro lado, Bucci e Forcellini (2007) enfatizam o ciclo de vida como um todo, porém tendo o ciclo de vida do produto como referência para a embalagem. Além disso, não avançaram na operacionalização de métricas de avaliação. O ciclo de vida por trazer uma perspectiva sistêmica da embalagem, enrobustecendo o projeto, minimizando a chance de que algum fator seja esquecido e que possa levar a falhas da embalagem. As métricas, por sua vez, são formas de verificar se algo não foi contemplado, de assegurar que o projeto seguiu um determinado curso e que pode trazer um melhor desempenho da embalagem para as etapas de uso e descarte.

Os métodos também trouxeram ferramentas para auxiliar no desempenho de embalagens sustentáveis, destaca-se a análise de ciclo de vida (ACV). A avaliação do ciclo de vida é um processo de avaliação do desempenho ambiental associadas a um produto, calculando a energia e os materiais usados e os resíduos e emissões liberados ao longo de todo o ciclo de vida (NIERO; OLSEN, 2016). Em relação à sustentabilidade na embalagem, é importante analisar todo o ciclo de vida e avaliar múltiplos impactos para reduzir o impacto ambiental. Os sistemas de embalagem consomem recursos naturais e energia, geram resíduos e emitem poluentes. Portanto, a LCA tornou-se uma ferramenta de apoio à decisão no design de embalagens (EARLY et al., 2009).

As falhas em projetos de embalagens podem ocorrer em diversos pontos, tais como problemas de comunicação com o consumidor (JERZYK, 2016; SUDBURY-RILEY, 2014); inviabilidade econômico financeira de projetos sustentáveis (ANANDA et al., 2017); os aspectos relacionados a contaminação de produtos mal acondicionados ou ocasionados pela matéria-prima utilizada para fabricação de embalagens (HAMOUDA et al., 2019; MOHAREB et al., 2017); Sobre a embalagem geradora de resíduo (CHEN et al., 2019; CHENG et al., 2015); sobre a logística reversa da embalagem (YUSUF et al., 2017), dentre outros.

Sob o ponto de vista da área de conhecimento, a embalagem não é propriedade de uma disciplina em especial, ela se encontra explorada em diversas áreas, tais como o design e comunicação (JERZYK, 2016; TIRPUDE; ALAM; SAHA, 2019), as engenharias (ELHUSSIENY et al., 2020; THOMOPOULOS et al., 2019), a química (AL-TAYYAR; YOUSSEF; AL-HINDI, 2020; CAZÓN; VÁZQUEZ, 2020), dentre outras (PAIANO; CROVELLA; LAGIOIA, 2020). Entender quais aspectos estão sendo abordados na literatura sobre a temática da embalagem no contexto da sustentabilidade auxilia no aproveitamento do conhecimento existente em situações reais e gera embasamento para construção de novos conhecimentos.

A necessidade de preparar projetistas para estarem atentos à exploração dos conceitos de sustentabilidade, desde as fases iniciais de design das embalagens é considerada uma oportunidade para desenvolver ferramentas e recursos que podem tornar a tarefa de design mais assertiva. Esta é uma oportunidade para pesquisadores que enfatizam métodos formais voltados ao desenvolvimento de embalagens sustentáveis criar ferramentas que apoiem os projetistas a integrar as informações. Um projetista que pretende criar uma embalagem eficiente e sustentável teria que se aprofundar nas fontes de informação de cada etapa do ciclo de vida, em busca de conteúdos que tornassem sua embalagem sustentável. No intuito de contribuir com este tema, o objetivo desta tese é propor um método para projetar embalagens, integrando os requisitos de sistemas e da sustentabilidade e a verificação do seu cumprimento ao longo do ciclo de vida.

Esta tese está organizada em cinco capítulos, três dos quais contemplam artigos. O primeiro artigo apresenta uma revisão sistemática de literatura e tem por objetivo reunir informações sobre embalagens no contexto da sustentabilidade e, por meio de uma visão sistêmica do conteúdo, identificar oportunidades e definir diretrizes para o design de embalagens. O segundo artigo propõe um corpo de conhecimento, Radar da Embalagem, que considera o arcabouço teórico próprio de cada etapa do ciclo de vida da embalagem, que oferece uma perspectiva ao mesmo tempo simples e sistêmica e que serve de diretriz para o projeto de embalagens sustentáveis. O terceiro artigo propõe um método sistêmico para desenvolver uma embalagem sustentável ao longo do ciclo de vida. O método foi testado em um caso real de uma embalagem projetada para acondicionar fatias de pizza comercializadas em estádios de futebol.

Entre os artigos, foram apresentados mapas conceituais de integração. O artigo 1 apresentou conteúdos importantes sobre embalagens sustentáveis, propôs através da integração de 14 métodos de projetação de embalagens extraídos da literatura um modelo comum, composto de 5 etapas e da mesma forma, o ciclo de vida da embalagem, composto por 8 fases. Estes elementos foram importantes para a concepção do Radar da embalagem, estudado no artigo 2. Por sua vez, o artigo 2 apresentou um corpo de conhecimento extraído da literatura, estruturado a partir das fases do ciclo de vida da embalagem. O Radar da embalagem foi integrado ao método proposto no artigo 3, contribuindo para auxiliar o projetista nas fases iniciais de briefing e planejamento.

## 1.1 TEMA E JUSTIFICATIVA

O tema desta tese relaciona-se com a embalagem no contexto ambiental, integrando os requisitos de sistemas e da sustentabilidade e a verificação do seu cumprimento ao longo do ciclo de vida.

Sob a perspectiva de sistemas, um projeto de embalagem para ser sustentável deve levar em consideração o ciclo de vida do produto/serviço que está sendo desenvolvido e o ciclo de vida da própria embalagem (MANZINI, 2005; PELTIER, 2009). Deve ser vista sob uma perspectiva sistêmica e de complexidade, para atender suas várias funções, atender os *stakeholders* envolvidos e seus requisitos projetuais, muitas vezes conflitantes (SASTRE et al., 2020). As grandes empresas possuem departamentos de desenvolvimento de embalagem, separados das áreas de desenvolvimento de produto, compostos por profissionais das áreas de marketing, pesquisa e desenvolvimento, área jurídica, regulatórios e sustentabilidade. Nas empresas pequenas e médias os projetos de embalagem são terceirizados por meio de escritórios de design ou, em outros casos, as soluções são oferecidas pela própria indústria convertedora de embalagem (BUCCI; FORCELLINI, 2007; MESTRINER, 2002; NEGRÃO; CAMARGO, 2008).

Uma boa parte dos escritórios de design de embalagem no Brasil atuam somente com design gráfico, segundo o perfil de empresas cadastradas no guia de fornecedores da Associação Brasileira de Embalagem, ABRE (2022). Estas empresas trabalham para atender as funções expositivas da embalagem, chamar atenção do consumidor no ponto de venda, despertar desejo de compra, proporcionar experiências positivas com os usuários, transmitir informações e suporte para ações promocionais, (marketing) (MESTRINER, 2002). Estas ações buscam transformar a embalagem em um instrumento de venda do produto exposto nas gôndolas de supermercados ou outros canais de distribuição, como o e-commerce, por exemplo. Por sua vez, a indústria convertedora de embalagens tem como foco a produção, seu desenvolvimento acaba se tornando uma parte secundária, mas importante para viabilizar sua produção e atender aos clientes que não dispõem de projetos estruturais. As grandes empresas produtoras de embalagens oferecem aos seus clientes uma área de suporte para projetos estruturais. As soluções disponíveis para a produção de grandes volumes estão direcionadas para atender os anseios produtivos, ou seja, a fabricação da embalagem, o envase do produto, sua distribuição, contenção e armazenamento (DAVISON; REDHILL, 1998; MOURA & BANZATO, 1997).

As indústrias de embalagens de menor porte, preparadas para atender demandas em menores quantidades, muitas vezes não dispõem de uma área específica para desenvolvimento estrutural. Desta forma, as soluções oferecidas ao mercado acabam sendo adaptações de projetos já executados e geralmente direcionados para a capacidade produtiva da empresa, seus processos de impressão e acabamentos, bem como a matéria-prima utilizada por uma determinada indústria (RONCARELLI, 2010). Estas soluções atendem parcialmente a demanda do mercado por meio da replicação e adaptação de projetos existentes, em muitos casos relacionados a custo baixo por utilizarem as mesmas matrizes de outros projetos. Por exemplo, uma empresa fabricante de geleia irá buscar um fornecedor que atenda um dos seus concorrentes para aproveitar a matriz do seu frasco e replicar o que já existe, inserindo-se em uma linguagem gráfica característica de sua categoria de produto.

A embalagem exerce suas funções em um ambiente complexo, sistêmico e multidisciplinar, apresentado no decorrer dos artigos que compõem essa tese.  As grandes industriais que adotaram uma área de desenvolvimento de embalagens, devido à sua importância, principalmente como componente do custo de um produto e instrumento de venda, conseguem desenvolver projetos que buscam satisfazer toda a sua cadeia e ainda, contam com o auxílio de grandes indústrias de embalagens. Neste cenário favorável ao desenvolvimento, o desafio é priorizar os requisitos relacionados à sustentabilidade, o que em muitos casos não são economicamente atrativos para a indústria de envase (GUSTAVO et al., 2018) .

Nas pequenas e médias empresas, as soluções estão dispersas entre os elementos que compõem o ciclo de vida da embalagem, especificamente, a indústria de matéria-prima, a indústria de embalagens e o escritório de desenvolvimento. Os clientes estão condicionados ao que o mercado tem a oferecer, o que nem sempre é o mais adequado para atender aos requisitos dos envolvidos no processo e tão pouco as soluções relacionadas à sustentabilidade (SASTRE et al., 2019, 2020). Recomenda-se o entendimento prévio sobre os principais elementos que compõem um projeto de embalagem, seus requisitos ambientais, bem como suas interações para garantir que ele seja sustentável.

Diante deste cenário, a justificativa para a concepção desta tese inicia com a questão de pesquisa e os objetivos geral e específicos e o método de pesquisa apresentados a seguir.

## 1.2 PROBLEMA DE PESQUISA

Como viabilizar que o método de projeto de uma embalagem integre os requisitos de sistemas e da sustentabilidade ambiental e permita a verificação do seu cumprimento ao longo de todo o seu ciclo de vida?

## 1.3 OBJETIVO GERAL

O objetivo desta tese é propor um método para projetar embalagens, integrando os requisitos de sistemas e da sustentabilidade e a verificação do seu cumprimento ao longo do ciclo de vida.

## 1.4 OBJETIVOS ESPECIFICOS

i) Entender o estado da arte sobre embalagens no contexto da sustentabilidade, identificar oportunidades e definir diretrizes para o design de embalagens.

ii) Criar um corpo de conhecimento que considere o arcabouço teórico próprio de cada etapa do ciclo de vida da embalagem, que ofereça uma perspectiva ao mesmo tempo simples e sistêmica e que sirva de diretriz para o projeto de embalagens sustentáveis.

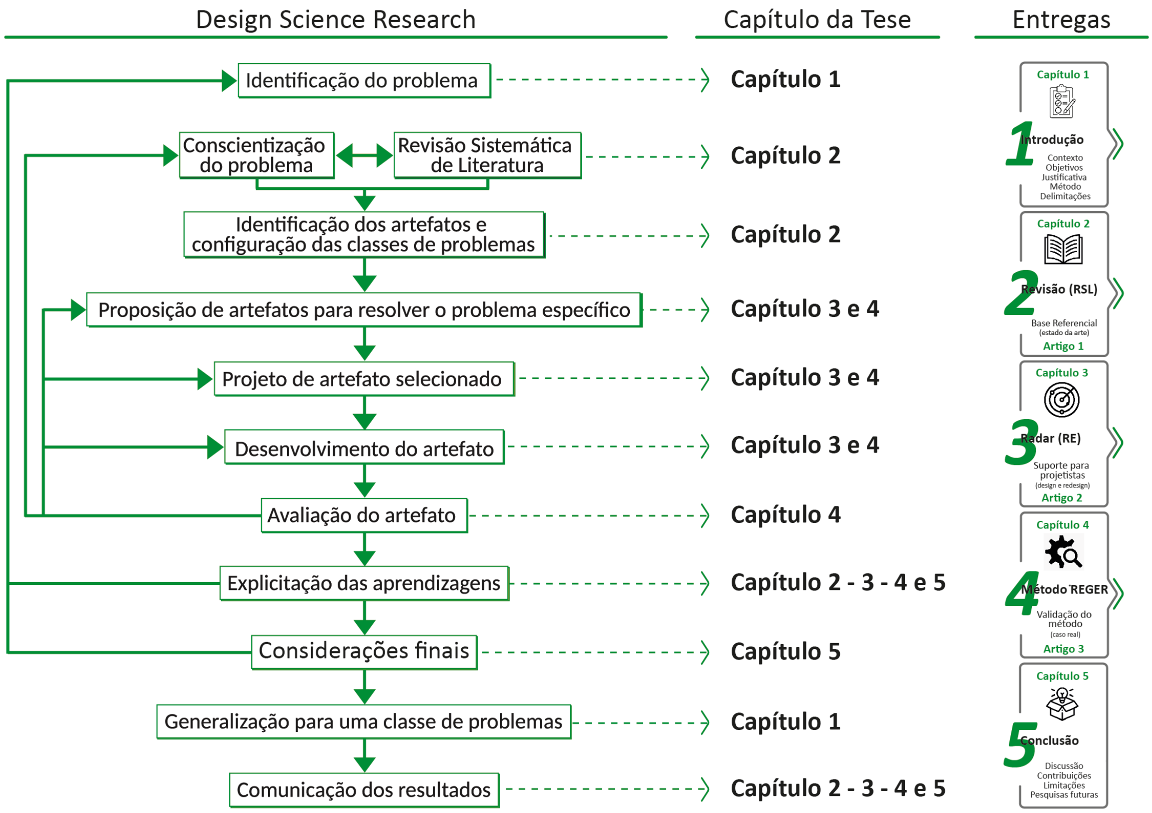
iii) Definir requisitos de avaliação da sustentabilidade ambiental do projeto da embalagem por todo seu ciclo de vida e validá-los.

## 1.5 MÉTODO DE PESQUISA

Para cumprir os objetivos desta tese, seguiram-se as etapas propostas do método de pesquisa construtivista, *Design Science Research* (DSR), apresentado na Figura 1. O *Design Science* é a ciência que procura consolidar conhecimentos sobre o projeto e desenvolvimento de soluções para melhorar sistemas existentes, resolver problemas e criar artefatos (DRESCH; LACERDA; JUNIOR, 2015). Um problema relevante e sua relação teórico/prático pressupõe novas formas de pesquisa, o DSR busca contribuir com esta aproximação (LANAMÄKI; STENDAL; THAPA, 2011). O DSR é um método de pesquisa rigoroso para projetar artefatos, avaliar o que foi desenvolvido e comunicar os resultados alcançados (DRESCH; PACHECO LACERDA; CAUCHICK-MIGUEL, 2019).

Para fundamentar o método proposto, foi utilizado o modelo sugerido por (DRESCH; LACERDA; JUNIOR, 2015), composto por 12 etapas principais (Figura 1). As setas centrais (de cima para baixo) indicam a ordem direta para a realização de cada um dos passos. As setas laterais (de baixo para cima) representa os possíveis *feedbacks* que podem ocorrer entre as etapas e ao longo da execução do método. Para cada etapa do método há um indicativo dos capítulos da tese que atenderam a demanda. As entregas de cada etapa foram identificadas com os mesmos números dos capítulos e estão contidos na Figura 1 para facilitar o entendimento.

**Figura 1** – Etapas da metodologia proposta nesta tese




Fonte: Adaptado de Dresch, Lacerda & Junior (2015).

O artigo 1 inicia na identificação e conscientização do problema através da revisão sistemática de literatura e destaca os artefatos e configuração das classes de problemas. O artigo 2 inicia pela conscientização do problema, transcorre por uma pesquisa bibliográfica e finaliza no desenvolvimento do artefato, apresentando o Radar da embalagem. O artigo 3 inicia pela conscientização do problema, desenvolve e apresenta o artefato denominado método REGER e por fim, avalia o artefato através de um caso real. As demais etapas foram discutidas nos capítulos 1 e 5 do presente estudo.

A seguir, apresenta-se o desdobramento das etapas:

**i) Identificação do problema:** O problema a ser investigado por meio da DSR surge, principalmente, do interesse do pesquisador em estudar uma nova ou interessante informação, encontrar resposta para uma questão importante, ou a solução para um problema pratico ou uma classe de problemas. A lacuna de pesquisa surgiu a partir do interesse do autor em aprofundar seus estudos na área de embalagem no contexto da sustentabilidade, sendo esta sua área de atuação profissional. Em razão disto, realizou-se um levantamento inicial na literatura para verificar o estado da arte da embalagem no contexto da sustentabilidade.

**ii) Conscientização do problema:** É nessa etapa que o pesquisador deve buscar o máximo de informações possíveis, assegurando a completa compreensão de suas facetas, causas e contextos. Além disso, precisam ser consideradas as funcionalidades do artefato, a performance esperada, bem como seus requisitos de funcionamento. Nesta etapa iniciou-se a consulta às bases de referências da literatura e a construção do conhecimento relativo à sustentabilidade de embalagens e seu projeto. Foram realizadas pesquisas em livros e artigos de modo aleatório e testes de *strings* de busca para a revisão de literatura. No artigo 2, a conscientização do problema teve por propósitos: i) consolidar as etapas do projeto de embalagem por meio da análise de autores que tratam de método de projeto para embalagens; ii) entender e analisar o objetivo das fases iniciais do projeto (Briefing e planejamento), elencando requisitos do projetista para elas. Por fim, o artigo 3 apresenta a análise de 14 métodos de projetação de embalagens, e respectivas ferramentas para auxiliar em cada fase do projeto e os elementos relacionados à sustentabilidade trazidos pelos métodos analisados. Neste caso, a conscientização do problema teve por propósitos: i) consolidar as etapas do projeto de embalagem por meio da análise de autores que tratam de método de projeto para embalagens; ii) entender e analisar o objetivo das fases do projeto (Briefing; planejamento; desenho; implantação e validação), elencando requisitos do projetista para cada uma delas.

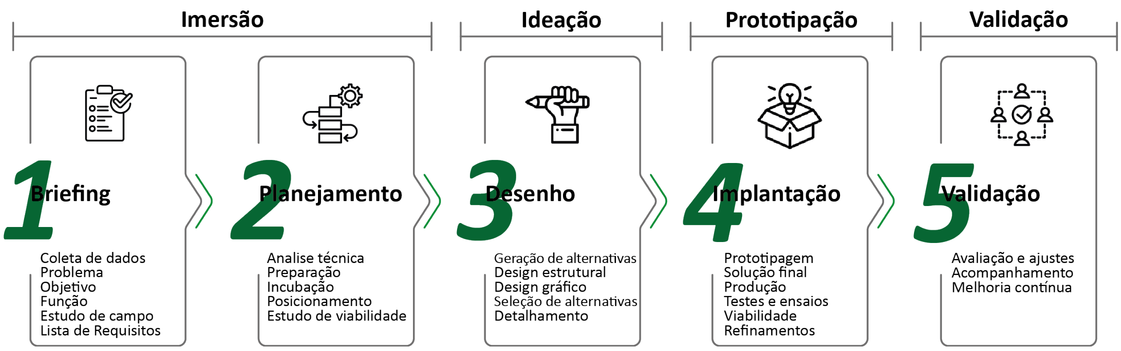
**iii) Revisão sistemática de literatura:** Após uma busca inicial, optou-se em realizar uma revisão sistemática de literatura no artigo 1, reunindo informações sobre embalagens no contexto da sustentabilidade e através de uma visão sistêmica do conteúdo, identificar oportunidades e definir diretrizes para o design de embalagens. A *string* de pesquisa foi composta pelas palavras-chave e pelos operadores booleanos “Pack * e Sustainab * e eco *”. A composição de palavras foi reduzida para retornar o maior número de publicações sobre o tema nas fontes pesquisadas: EBSCO, Emerald, Science Direct, Springer, Web of Science e Willey. Devido à generalização da expressão Pack * a palavra foi considerada apenas no título, para direcionar a busca dentro dos objetivos da pesquisa. Esta revisão sistemática de literatura contribuiu como base referencial para a concepção do Radar da embalagem e do método REGER.

**iv) Identificação dos artefatos e configuração das classes de problemas:** a Revisão sistemática de literatura apoiou a tarefa de identificar referências para o artefato a ser desenvolvido, um método de projeto de embalagens sustentáveis. A embalagem segue um método de desenvolvimento próprio, composto de diversas etapas.

A base referencial partiu de diferentes autores que tratam do assunto ao longo dos últimos 50 anos, tais como: (BERGMILLER, 1976; BROD, 2004; BUCCI; FORCELLINI, 2007; CARVALHO; MERINO; MERINO, 2008; CARVALHO, 2008; DUPIUS; SILVA, 2008; GIOVANNETTI, 1995; GRÖNMAN, 2013; GURGEL, 2007; MESTRINER, 2002; MOURA & BANZATO, 1997; NEGRÃO; CAMARGO, 2008; PEREIRA, 2012). Estes autores propõem nomes distintos para as etapas do projeto, às vezes semelhantes, às vezes complementares. Dentre os 14 métodos estudados (BROD, 2004; BUCCI; FORCELLINI, 2007; GRÖNMAN, 2013; PEREIRA, 2012) (Brod, 2004; apresentam-se como modelos orientados a projetos sustentáveis.

O quadro completo das etapas de cada autor pode ser consultado no link: https://drive.google.com/file/d/18G460IDr_Ft5_qDYfNUALSJGS_doVKsp/view?usp=sharing.

**Figura 2** – Artefato preliminar




Fonte: O autor

A classe de problemas utilizada para a concepção deste artefato preliminar são métodos para desenvolvimento de embalagens. Este modelo de artefato foi utilizado no capítulo 2 para classificar os artigos da revisão sistemática de literatura, no capítulo 3 (artigo 2), no referencial teórico e no capítulo 4 (artigo 3) no referencial teórico e para compor o método REGER. A análise de literatura permitiu insights e a ampliação de conhecimento de outros conteúdos que serviram como base para a construção do artefato. A primeira necessidade surgiu na ampliação do próprio conceito de embalagem, apresentado na introdução do presente estudo. Em relação aos conceitos pesquisados, a nova proposição classificou a embalagem como complexa e sistêmica sob a perspectiva de todo o seu ciclo de vida. O Radar da embalagem embora contribua para o projeto de uma embalagem não é suporte suficiente para atender os requisitos de projeto ao longo das fases briefing, planejamento, desenho, implantação e validação.

**v) Proposição de artefatos para resolver o problema específico:** Esta etapa é necessária pois as soluções quando consolidadas, precisam se adaptar a realidade em estudo. Neste caso, o problema específico são embalagens sustentáveis. O artefato proposto tem como foco desenvolver projetos ecologicamente corretos e algumas ações são direcionadas para esta finalidade.

**vi) Projeto de artefato selecionado:** Nesta etapa avalia-se as soluções formalizadas na etapa anterior que são satisfatórias para o problema em estudo. Considera-se as características internas e o contexto em que irá operar. Componentes, relações internas de funcionamento e limites e relações com o ambiente externo. Deve-se informar o desempenho esperado, que irá garantir uma solução satisfatória para o problema.

Sugere-se o uso do Radar da embalagem no método REGER, através de ícones, nas etapas de (briefing e planejamento), auxiliando no levantamento de informações importantes sobre o projeto de embalagem sustentável. O ponto de partida do método REGER traz à tona a real necessidade de uso de uma embalagem, incentivando o projetista a refletir sobre os objetivos do projeto. A representação gráfica do método orienta o profissional a iniciar o projeto levantando informações relacionadas as etapas de pós-uso e extração da matéria-prima.

Outro ponto relevante sobre o método apresentado é a integração das etapas de projeto com as fases do ciclo de vida, trazendo uma visão sistêmica e sustentável em um projeto de embalagem. Propõem-se através de requisitos, a avaliação do atendimento à sustentabilidade durante todo o desenvolvimento do projeto, buscando garantir a redução do impacto ambiental em todo o processo.

**vii) Desenvolvimento do artefato:** O desenvolvimento ocorreu a partir do esforço em reunir informações sobre embalagens no contexto da sustentabilidade através da revisão sistemática de literatura e na concepção de um corpo de conhecimento que considere o arcabouço teórico próprio de cada etapa do ciclo de vida da embalagem (Radar da embalagem). A partir do cruzamento das etapas de projeto e as fases do ciclo de vida, foi concebido um método para projetar embalagens denominado REGER, integrando os requisitos de sistemas da sustentabilidade e a verificação do seu cumprimento ao longo do ciclo de vida.

**viii) Avaliação do artefato:** Após o desenvolvimento do artefato, deve-se medir o comportamento do artefato na solução do problema. O capítulo 4 (Artigo 3) apresenta a aplicação do artefato em um caso real de projeto de embalagem sustentável, integrando os requisitos de sistemas da sustentabilidade e a verificação do seu cumprimento ao longo do ciclo de vida. O artefato foi testado em um caso real de redesenho de embalagem da área de alimentos (melhorias de um projeto existente). A escolha do caso obedeceu aos seguintes critérios definidos pelo cliente demandante e pela equipe do projeto: i) o caso deveria ter foco em sustentabilidade; ii) a embalagem deveria contemplar o maior número de elementos contidos no artefato proposto; iii) ser consumida em grandes volumes, por fim, iv) permitir acesso facilitado na empresa desenvolvedora e comprometimento dos responsáveis para coleta de dados e pesquisas de campo durante a aplicação do modelo proposto.

**ix) Explicitação das aprendizagens:** O objetivo desta etapa é assegurar que a pesquisa realizada possa servir de referência e como subsídio para a geração de conhecimento, tanto no campo prático quanto no teórico. Ao longo dos três artigos, foram apresentados as discussões e resultados, bem como oportunidades para futuros estudos ou aplicações. No capítulo 5 desta tese, são apresentadas e discutidas as principais contribuições teóricas e práticas desta tese, bem como as limitações da pesquisa e as sugestões para futuros trabalhos na área de embalagem em um contexto de sustentabilidade.

**x) Considerações finais:** Nesta etapa ocorre a formalização da conclusão, expondo os resultados obtidos com a pesquisa, bem como as decisões tomadas durante a execução. No capítulo 5 desta tese são apresentadas e discutidas as principais contribuições teóricas e práticas desta tese, bem como as limitações da pesquisa e as sugestões para futuros trabalhos na área de embalagem em um contexto de sustentabilidade.

**xi) Generalização para uma classe de problemas:** a generalização permite que o conhecimento gerado em uma situação especifica possa, posteriormente, ser aplicado a outras situações similares a que são enfrentadas por diversas organizações. Um dos maiores desafios na proposição do artefato consistiu em sua generalização para ser aplicado em qualquer projeto de embalagem, independente do tipo de material, porte da empresa, segmento de mercado, público-alvo, classificação e funcionalidades.

A estrutura do método apresentado permite sua aplicação para o desenvolvimento de uma simples caixa de embarque (embalagem terciária), até um projeto mais complexo, envolvendo a área da saúde, por exemplo. O que difere um projeto do outro é o nível de profundidade, número de pessoas envolvidas e o porte da empresa. A sustentabilidade é a premissa para aplicação do método, aferida em todas as etapas do projeto.

**xii) Comunicação dos resultados:** A última etapa compreende na publicação dos resultados, com o intuito de atingir o maior número possível de interessados na temática, tanto na academia como no mercado. No caso desta pesquisa, a comunicação ocorreu através da publicação de três artigos em periódicos distintos e através desta tese. Em relação ao mercado, estes artefatos serão utilizados em projetos reais executados pelo escritório de desenvolvimento de embalagens do autor, bem como na apresentação dos resultados em eventos e entidades de classe relacionadas ao universo da embalagem.

## 1.6 DELIMITAÇÕES DO ESTUDO

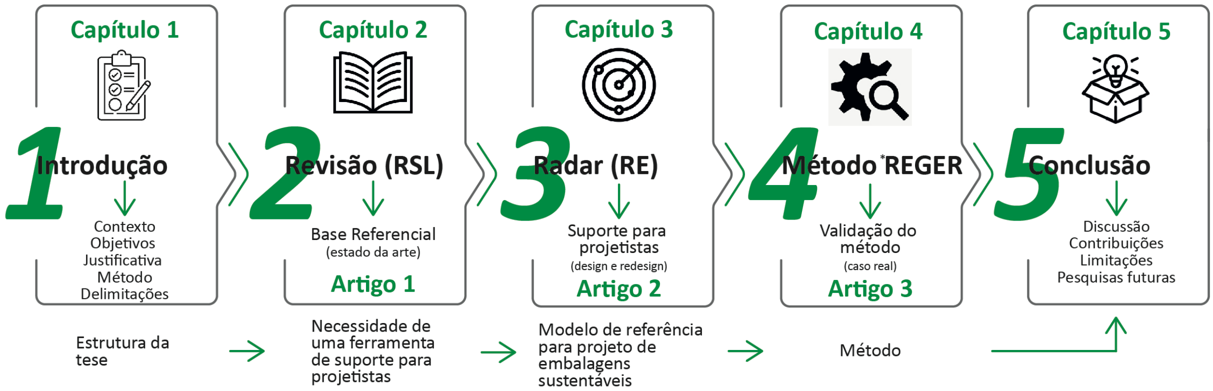
Os desdobramentos da pesquisa que compõe o conjunto desta tese são realizados em projetos de embalagens. A embalagem é parte integrante do produto, neste caso, o método proposto não considera o processo de desenvolvimento de produto (PDP). O método proposto pode ser aplicado em qualquer tipo de embalagem, independente da classe, do material ou funcionalidade.

O presente estudo foi direcionado para pesquisadores e projetistas de embalagens, profissionais que atuam diretamente ou indiretamente em projetos, sejam engenheiros, designers, publicitários, de áreas afins ou autodidatas.

## 1.7 ESTRUTURA DA TESE

Esta tese está organizada em cinco capítulos (Figura 3). O primeiro capítulo mostra a visão geral da pesquisa realizada, o contexto e a importância em desenvolver embalagens sustentáveis, os objetivos, a justificativa, o método de pesquisa e as delimitações da tese.

**Figura 3** – Estrutura da tese




Fonte: O autor

Os capítulos dois, três e quatro apresentam os artigos desenvolvidos para atingir o objetivo desta tese O primeiro artigo expõe o estado da arte sobre embalagem no contexto da sustentabilidade, o segundo artigo cria um corpo de conhecimento denominado Radar da embalagem e o terceiro, apresenta e aplica o método para desenvolvimento e avaliação de embalagens denominado REGER. O quinto e último capítulo apresenta as considerações finais da tese, discutindo os resultados apresentados, abordando aspectos teóricos e práticos, evidenciando contribuições, limitações e pesquisas futuras.

## 2. ARTIGO 1 A SYSTEMATIC LITERATURE REVIEW ON PACKAGING SUSTAINABILITY: CONTENTS, OPPORTUNITIES, AND GUIDELINES

Link da publicação na revista Sustainability: https://www.mdpi.com/2071-1050/14/11/6727

**Abstract:** The relationship between packaging and sustainability has caused the evolution of literature towards the minimization of environmental damage. The task of packaging professionals is becoming more demanding, as they need to collect information from distinct topics to stay up to date. The aim of this research is to gather information on packaging in the sustainability context to provide a systemic view of the contents, to identify opportunities, and define guidelines for packaging design. A systematic literature review of 472 papers was performed. The first step was a bibliographic search using Pack*, Sustainab*, and eco* as keywords. Secondly, the content analysis revealed the emergence of nine categories grouped in four clusters. These categories and nineteen subthemes were considered research opportunities. Going beyond the coding units of the content analysis, we have used context units to propose (i) the gathering of technical procedures to support the design phases of sustainable packaging; and (ii) the proposition of a framework based on the life cycle stages and design phases. At last, we have provided insights and guidelines that can be useful for packaging professionals.

**Keywords:** packaging; sustainability; circular economy; systematic literature review; design guidelines

### 2.1 INTRODUCTION

Packages are envelopes, containers, or any form of covering, removable or not, intended to enclose, protect, maintain the products in use for longer periods, or facilitate their marketing. Packaging is a complex technical and commercial system whose objective is to protect a given content from the production process to consumption, aiding its identification, promotion, and negotiation [1–3].

Sustainability has become one of the functions of packaging, along with ensuring products' quality and safety, enabling product communication, and facilitating transportation and logistics [4]. Considering the development of sustainable packaging, the environmental sustainability pillar is especially relevant [5]. Moreover, sustainable packaging contributes to minimizing the ecological footprint of companies and saving their resources [6].

In 2019, the total value of packaging worldwide was estimated to be approximately USD 917 billion Smithers [7]. A study published in "The Future of Global Packaging to 2024" shows that demand for packaging will grow 2.8% per year and peak at USD 1.05 trillion in 2024 Smithers [7]. According to studies of the World Packaging Organization, the food sector alone will reach USD 400 billion in packaging production by 2025 WPO [8]. The Global Packaging Trends 2020 from Mintel [9] listed two sustainability related packaging trends. The first trend is that packaging manufacturers and brands must continue developing and commercializing innovations with recyclable materials. The second trend is in store refills; with the rapid growth of independent package free stores. This is leading retailers in the entire sector to consider creating opportunities to refill products instead of using disposable packaging Mintel [9]. The same study reveals that 'responsible' packaging will reinforce the 'sustainable' packaging concept, since there is a relationship between responsibility and the social pillar of sustainability. This constitutes a practical approach that brand owners must promote and defend. Consumers have to act accordingly by valuing the adequate use and disposal of packaging. Once a more responsible packaging choice has been made, brands can use messaging to make consumers aware of why a specific packaging format or material has been used. More importantly, they may use the same strategy to educate consumers on what action they can take towards reuse or proper disposal Mintel [9].

According to Lu et al. [10] packaging excess on the planet challenges the sustainable development of our society. Under the perspective of the circular economy approach, the waste problem has to be addressed from the early design stage, which includes packaging projects Ellen Macarthur Foundation [11]. Additionally, the circular model is founded on economic, natural, and social capital concepts, always supported by a transition to renewable energy sources. Therefore, it is evident that the responsibility of packaging developers, manufacturers, and other professionals involved in packaging development is to respond to the ever increasing demands of the current scenario.

Although packaging seems simple from the structural standpoint, it is highly complex from the systemic life cycle point of view. Project definitions concerning the type of materials and format, for example, may impact its function, production stages, distribution, commercial actions, its adequate use/discard by consumers, and ultimately the environmental damage. Petljak et al. [12] reinforce that the materials used in packaging and their waste have a very harmful influence on the environment, and they explain the tendency to develop efficient and effective biodegradable packaging.

Packaging complexity is also revealed by the fact that it does not belong to a particular area of expertise. It is explored in design and communication [13,14], engineering [15,16], and chemistry [17,18], among others [19]. The number of systematic literature reviews about packaging evidence the complexity of packaging. Some of these literature reviews focus on materials [20–24]. Other reviews focus on food packaging [25–29]; while others explore the dimensions or triple nature of sustainability [30–34]. Some packaging reviews are not specific [6,35–38]. Considering that such research and reviews are spread over different literature domains, the systemic analysis of the knowledge is an essential and challenging task for professionals in the packaging field.

The starting premise is that packaging must be designed to cause the least environmental impact possible. The project must be supported by tools similar to the life cycle assessment and inventories that minimize its carbon footprint and environmental impact. Packaging must meet market criteria and be developed within acceptable financial costs. It has to be socially and culturally appropriate (reflecting, for example, the target audience's lifestyle), with a social enabler that encourages consumers to find alternative uses for it. If the package design fails to provide alternative uses, consumers must be able to dispose of it in an environmentally correct way [12,39,40]. The circular economy concept is relevant in the search for solutions to the problem of packaging waste generation. The transition from a dominant linear economy to a model based on circularity and design by intention may create a new basis that is essential for the market economy and use of packaging [41]. Considering the extent of the problem presented, the following research questions arise:

RQ 1—What has been discussed, in the literature, about sustainability strategies applied to the packaging life cycle (extraction of raw material, raw material transformation, graphic and structural design, packaging manufacturing, filling process, sale, use, and post-use)?
RQ 2—How has the literature supported packaging professionals' practice in the context of the circular economy and sustainable packaging?
RQ 3—What research opportunities can emerge from the current literature on sustainable packaging?

The authors ground their research on the premise that gathering knowledge from the extant literature on sustainable packaging may provide a systemic view to professionals and researchers and provide the foundations for developing new types of knowledge.

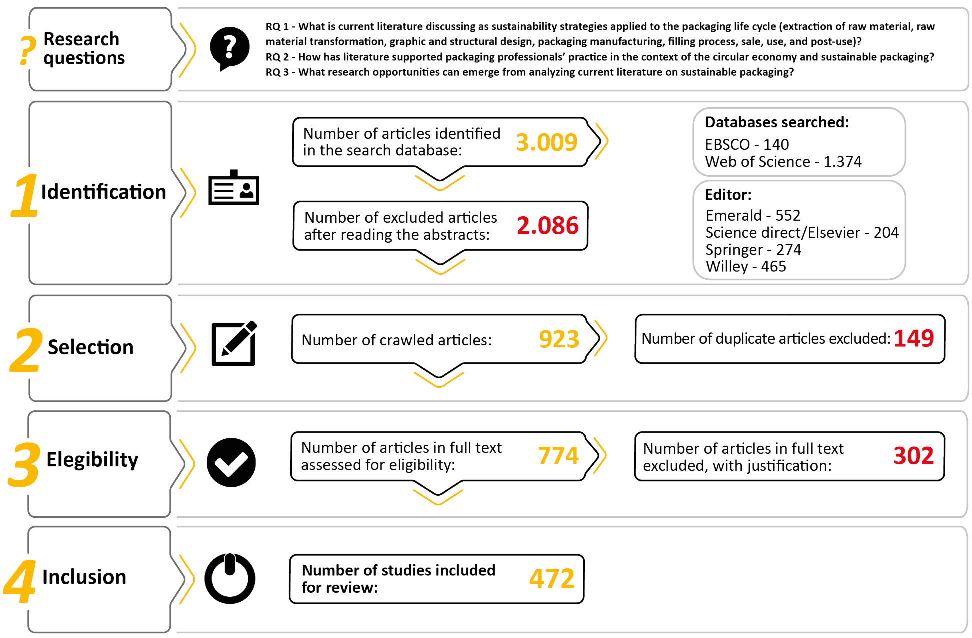
## 2.2 MATERIALS AND METHODS

The method adopted is the systematic literature review (SLR), with an emphasis on publications that addressed packaging in the sustainability context. The documents identified were analyzed according to the following two approaches: (i) bibliographic analysis, which provided a quantitative view of the main titles of journals and publications [42], and (ii) a qualitative study using content analysis adapted from Bardin [43], Bickman et al. [44] and Moraes, [45].

### 2.2.1 Systematic Literature Review

The protocol recommendation of Moher et al. [46] was used as a basis for the SLR. It consists of four steps (Figure 4) that aim to support the authors in improving the reporting of systematic reviews and meta-analyses. The items considered for the bibliographic analysis were publication year, journal, area of knowledge and repository, countries, universities, and research method adopted. The authors used the VOSviewer® software, version 1.6.18, create to Leiden University, Leiden, The Nederlands, for keyword analysis, and authorship and coauthorship analysis. This tool allows constructing and visualizing bibliographic networks.

**Figure 4.** Systematic literature review protocol




**Fonte:** The authors

The search string was composed of the following keywords and Boolean operators: "Pack * and Sustainab * and eco *." We adopted a reduced keyword search to retrieve the largest number of publications about the topic from the searched sources EBSCO, Emerald, Science Direct, Springer, Web of Science, and Willey. Based on the eligibility criteria defined, only articles published in English were selected. Due to the generalization of the term Pack *, the word was considered only in the title to restrict the search to the defined purposes. A set of 10 articles did not present their full text; hence, they were excluded from the retrieved set. In the first search, the total number of articles retrieved was 3009. After applying the exclusion criteria, 472 articles were selected (Figure 4). The links to all the articles retrieved in the search and all phases of the SLR protocol are presented in Appendix A.

In phase 1 (identification), the articles that failed to meet the research topic were excluded. For instance, they were removed whenever they focused on tourism packages, service packages, software packages, quantitative study packages, statistical packages, energy packages, economical packages, technological packages, guidelines packages, control packages, benefits packages, policy packages, intervention packages, work packages, logistical packages, fiscal packages, energy packages, simulation packages, legislative packages, benefits packages, and healthcare packages.

Preliminary searches have indicated that the number of articles increased after 1990. Therefore, this analysis comprised 30 years of publications, starting in 1990. The search was performed from April to May 2020, when the gathering ended. The results and search criteria in each database and publishers are described in Table 1.

**Table 1**. Results and search criteria in each source.

| Sources | Search criteria | String | First search | Excluded | Analyzed |
|---|---|---|---|---|---|
| EBSCO research date: May 06th, 2020. | Time range: all years; article part: Pack* in title and Sustainab* and eco* in abstracts; documents: article; areas: all; the search criteria of containing the word "packaging" in the title was added to reduce the high number of articles (12,204). | Pack* AND Sustainab* AND Eco*. | 140 articles | 79 articles | 61 articles |
| Emerald research date: May | Time range: all years; article part: Pack* in abstract and Sustainab* and eco* in all the | Pack* AND Sustainab* AND Eco*. | 552 articles | 489 articles | 63 articles |

| | | | | | |
|---|---|---|---|---|---|
| 07$^{th}$, 2020. | articles; documents: articles; areas: all; search. | | | | |
| Science Direct/Elsevier research date: May 05$^{th}$, 2020. | Time range: all years (1978 to 2020); article part: all articles; documents: articles; areas: all; the criterion of containing the word “packaging” in the title was added to reduce the high number of articles (12,204 articles). | Packaging AND Sustainability AND eco (this base does not accept asterisk but considers similar words). | 204 articles | 27 articles | 177 articles |
| Springer research date: May 03$^{rd}$, 2020. | Time range: all years; article part: all; documents: articles and conference articles; areas: all; search string. | Pack* AND Sustainab* AND Eco*; containing pack* in the title. | 274 articles | 147 articles | 127 articles |
| Web of science research date: April 30$^{th}$, 2020. | Time range: all years (1945 to 2020); article part: topic (title, abstract, author keywords and keywords); documents: articles and reviews; areas: all; main collections of Web Science. | Pack* AND Sustainab* AND Eco*. | 1374 articles | 970 articles | 404 articles |
| Willey research date: April 26$^{th}$, 2020. | Time range: all years (1957 to 2020); article part: abstract; documents: article; areas: all. | Pack* AND Sustainab* AND Eco*. | 465 articles | 374 articles | 91 articles |

**Fonte:** The authors

In phase 2 (selection), 923 articles were considered, and 149 duplicated articles were excluded. In phase 3 (Eligibility), based on the criteria defined and after the full reading of the articles, 302 articles were excluded out of the 774 because they did not address the research topics of packaging and sustainability. In phase 4 (inclusion), a total of 472 articles were selected for the literature review. The bibliographic references and content extraction from articles were managed using Mendeley® software, version 2.70.0, create to Elsevier Inc., Amsterdam, The Nederlands. Appendix A presents the link to access the articles and notes. The analyses of keywords, authors, and coauthors were performed with VOSviewer® software, version 1.6.18, create to Leiden University, Leiden, The Nederlands.

### 2.2.2 Content Analysis

The content analysis' objective was to guide information exploration and reduce subjectivity in the qualitative analysis [44]. The content analysis was developed grounded on the following two coding units: (i) sustainability, and (ii) circular economy, terms that were included in the search string. We used as context units (i) packaging life cycle stages and (ii) the packaging design stages. These context units were selected because they are the guiding dimensions in the creative process of packaging design. The decision for two levels of analysis allowed for a more targeted reading focused on our study objective, thus, serving as classification categories for the findings. Lastly, while reading the 472 articles selected, other units emerged and were used as classification subcategories. More details on article classification are described in Sections 3.2 and 3.2.1.

## 2.3 RESULTS

A growth trend was observed in the publications on the subject of packaging over the years. Considering the current protocol, no publications were identified in 1991, 1992, 1994, and 1995. In 1993 and from 1996 onwards, few publications emerged each year, and a continuous growth started in 2013. The period from 2013 to 2020 constitutes 82% of the articles retrieved, revealing the growing interest of scholars on the subject in the last years. An illustrative chart of publications by year can be observed in Supplementary Material—S1.

### 2.3.1 Bibliographic Analysis

The classification of articles by areas of knowledge is presented in figure 5, based on the proper categories indicated by the journals' editors. Research topics specific to each article were reported using electronic spreadsheets (Microsoft Excel®). In a second classification, journals were grouped by knowledge areas, resulting in 21 general areas, published in 20 digital repositories. The detailed table can be observed in Supplementary Material—S2.

**Figure 5.** Classification of articles by knowledge area

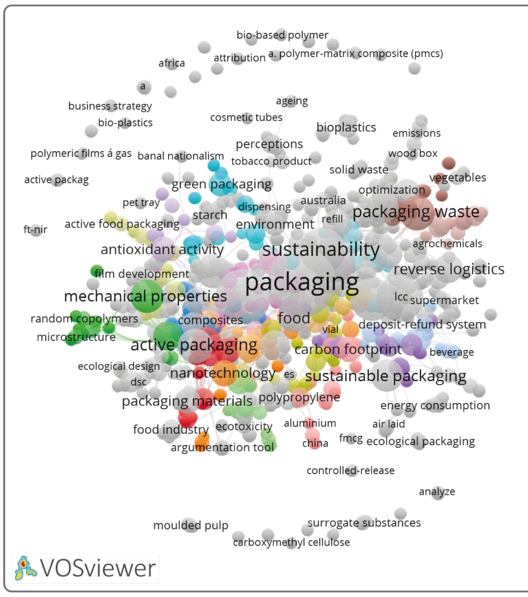
| Nº | Area | Nº articles |
|---|---|---|
| 01 | Sustainability | 151 articles |
| 02 | Food Science | 78 articles |
| 03 | Materials | 73 articles |
| 04 | Interdisciplinary | 54 articles |
| 05 | Packaging | 25 articles |
| 06 | Chemistry | 21 articles |
| 07 | Management | 12 articles |
| 08 | Engineering | 11 articles |
| 09 | Marketing | 10 articles |
| 10 | Animal and Agriculture | 7 articles |
| 11 | Business | 7 articles |
| 12 | Technology | 5 articles |
| 13 | Biology | 4 articles |
| 14 | Innovation | 3 articles |
| 15 | Design | 3 articles |
| 16 | Medicine | 2 articles |
| 17 | Economy | 2 articles |
| 18 | Tourism | 1 articles |
| 19 | Communication | 1 articles |
| 20 | Pharmaceutical | 1 articles |
| 21 | Physics and Astronomy | 1 articles |

**Fonte:** The authors

Figure 5 confirms that the topic "packaging" is distributed in various knowledge areas. This finding reinforces the initial premise of our study and emphasizes the multitude of professionals involved in the subject of "packaging sustainability". Hence, we aim to provide a panorama of the main practices, methods, and tools studied within this context. Thus, the "sustainability" analysis unit constitutes the largest number of publications, with 151 research articles (32%). The "circular economy" analysis unit encompasses approximately 5% of the articles. Such a smaller number of publications is not surprising, as this terminology is relatively new. Although the circular economy concept has existed since the 1970s under other terminologies, it is rising, and packaging is a relevant item within this context.

The analysis with VOSviewer® revealed 92 clusters, which are groups of keywords formed based on similarities or proximity. The largest cluster included 37 items, covering relevant topics, such as materials, food, and the transformation process. The association among these topics is coherent since the selection of materials and processes for the quality and safety of food packaging has been a relevant investigation challenge.
The "occurrences" column in Figure 6 indicates the number of articles in which a term occurs at least once.

**Figure 6.** Density of keyword occurrence in articles (https://www.vosviewer.com)




| Nº | Keyword | Ocurrences | Total link strength |
|---|---|---|---|
| 01 | Packaging | 88 | 419 |
| 02 | Food Packaging | 49 | 210 |
| 03 | Circular Economy | 32 | 153 |
| 04 | Sustainability | 31 | 151 |
| 05 | Recycling | 28 | 128 |
| 06 | Life Cycle Assessment | 27 | 121 |
| 07 | Active Packaging | 16 | 84 |
| 08 | Mechanical Properties | 14 | 74 |
| 09 | Life Cycle Assessment (LCA) | 13 | 68 |
| 10 | Biodegradable | 15 | 67 |
| 11 | Packaging Waste | 16 | 64 |
| 12 | Sustainable Packaging | 13 | 63 |
| 13 | Food | 09 | 62 |
| 14 | Biopolymers | 09 | 52 |
| 15 | Nanocomposites | 07 | 51 |
| 16 | Barrier Properties | 10 | 50 |
| 17 | LCA | 11 | 49 |
| 18 | Nanotechnology | 08 | 48 |
| 19 | Waste Management | 10 | 47 |
| 20 | Reverse Logistics | 10 | 46 |
| 21 | Shelf Life | 11 | 45 |
| 22 | Food Waste | 09 | 44 |
| 23 | Nanoparticles | 07 | 41 |
| 24 | Antimicrobial Activity | 09 | 38 |
| 25 | Chitosan | 08 | 38 |

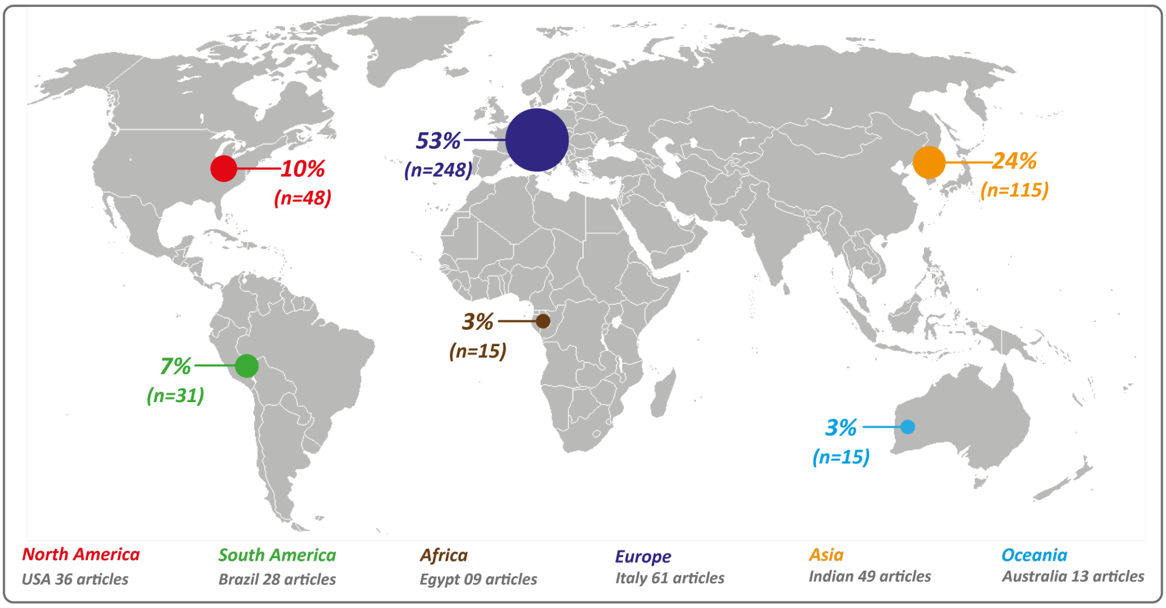
**Fonte:** The authors

The analysis reveals the subject trends gravitating around the term packaging. Considering the large number of articles returned (472), the density of occurrence of keywords guided the definition of categories for content analysis in the next step. The grouping of terms in VOSviewer® considered how terms were originally written; therefore, the total number of occurrences for fife cycle assessment (LCA) was 51 (27 + 13 + 11), which places this keyword in the second position, after packaging.

Another keyword worth mentioning is Active Packaging. The occurrence of this keyword reveals the importance that some technologies are gaining in the food packaging literature. This strategy will be further discussed in Section 3.2.1. The full density of keywords can be viewed in Supplementary Material—S3.

Figure 7 reveals the number of publications by country of origin of the first author in each article. The articles selected in this SLR were from 53 different countries. Figure 7 describes the list of publications by continent and the country with the highest publication in each of them. Europe constitutes the largest number of articles (53%), followed by Asia (24%) and North America (10%). The table containing all countries can be viewed in Supplementary Material—S4.

**Figure 7.** Classification of articles by continent




**Fonte:** The authors

**Figure 8.** Lists the ten research methods described in the articles

| Nº | Approach | Number of Articles |
|---|---|---|
| 01 | Experiment method | 151 |
| 02 | Literature review | 91 |
| 03 | Life cycle assessment | 68 |
| 04 | Case study | 51 |
| 05 | Qualitative method | 47 |
| 06 | Qualitative and quantitative method | 34 |
| 07 | Quantitative method | 26 |
| 08 | Action research | 02 |
| 09 | Phenomenological research | 01 |
| 10 | Ethnographic method | 01 |

**Fonte:** The authors

Experiments were mentioned in 32% of the articles, with emphasis on the analysis of materials. The literature review approach ranks second place (19%), with an emphasis on materials. The reviews focused on descriptions of the physical chemical behavior of the resources, their biodegradability, and other specificities. Properties of materials, such as aluminum, polymers, and other related knowledge are valuable information to be consulted by packaging developers. Life cycle assessment was cited as an approach in 14% of the articles. The content analysis in Section 3.2 will reinforce its relevance in the packaging context and the existing interdependence between life cycle assessment and other approaches.

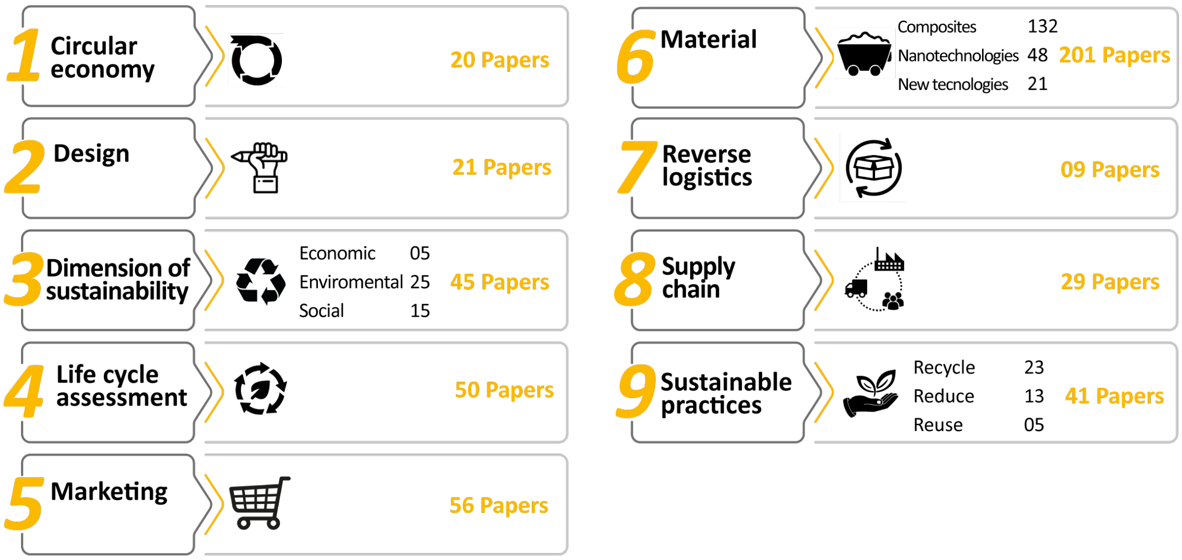
### 2.3.2 Content Analysis

The content analysis was performed to clarify the three research questions mentioned before. Coding units and context units were described in Section 2.2. The articles were grouped and may be consulted in Supplementary Material—S5.

*2.3.2.1 Categories for Classification of the Articles Analyzed*

The consensus of nine categories (Figure 6) was reached by comparing the groups named by the authors with the keywords previously observed in the VOSviewer® map (Figure 6).

**Figure 9.** Classification and total of articles by emerging categories




**Fonte:** The authors

As a general rule, each research article was classified in a given category, taking into consideration the main objective of each article. For example, the article was classified in the "life cycle assessment category" if the author's primary investigation goal was the LCA tool. If LCA was applied as a means to reach the goal, not as an end, the article was classified in another category. For instance, LCA was used as a measurement in some circular economy investigations. In such articles, the aim resided in studying the circular economy itself; therefore, circular economy was the category of choice for their classification.

Considering the nine categories, the content analysis presented subcategories described on a case basis in Section 3.2.1. Figure 9 shows that categories 3 (dimensions of sustainably), 6 (materials), and 9 (sustainable practices) were subdivided into three subcategories. The subdivision emerged from the initial reading of titles, and it helped in the analysis of the articles. The articles and their classifications are shown in Supplementary Material—S5.

The authors did not intend to make an exhaustive transcription of the content analysis of the articles since it would be impossible to summarize them in the body of a single publication. After analyzing all the contents, some articles were described in tables to provide an overview of specific and predominant topics in the SLR. (The tables can be evaluated in Supplementary Material—S6). These articles were selected according to the quality, current level of the contributions brought to the research, and journal relevance.

Each table presents five subcategories of classification, including (i) article objective, (ii) authors, (iii) main findings, (iv) life cycle stage, and (v) strategy applied to the packaging life cycle or to support professionals' practice. Subcategories (iv) and (v) were created to address RQ1 and RQ2, respectively.

For the (iv) life cycle stage subcategory, articles were classified as "filling process," for example, based on the packaging application reported in the article. If no specific type of packaging or application context was reported, the criterion was the life cycle stage name itself. Reference [47] for instance, studied the sectorial agreement of reverse logistics (RL) of packaging in Brazil; therefore, the RL process was the main theme, and the article was classified as "post-use". The same logic was used in all nine tables for classification in subcategories.

Finally, regarding RQ3, the symbol (Op#) indicated opportunities that emerged from content analysis.

*2.3.2.2 Categories in the Context of Sustainability*

Category 1, "circular economy" (CE), included 20 articles (4.2%) published between 2016 and 2020. Selected publications in each of the nine categories can be viewed in Supplementary Material—S6.

According to Foschi and Bonoli [48], plastic packaging has become an important driver to the transition towards circular economy models due to the industry's commitment to European policy European Commission [49]. At least two trends were observed in circular economy articles.

The first trend, namely the design/redesign of packages, is a proactive approach that is in alignment with the CE principle of "designing out waste and pollution". Concerning the frameworks for redesigning packaging, Niero and Hauschild (2017) compared the benefits and limitations of combining the cradle-to-cradle design protocol, the material circularity indicator, and the life cycle sustainability assessment (LCSA). The authors recommended using the LCSA framework to evaluate circularity strategies, since it is considered the most comprehensive and still operational framework with very broad coverage of impacts. They argue that with its life cycle perspective, it is best at preventing burden shifting between stakeholders in the value chain.

The second trend was the packaging waste valorization and management. Concerning the waste valorization studies, they have revealed the relevance of "people" and "environmental education" in the circular economy. Abuabara et al. [50] applied value focused thinking (VFT) and analytic hierarchy process (AHP) methodology to prioritize (RL) strategies according to interviewees' values. Buil et al. [51] demonstrated the positive effects of childhood education in the circular economy by teaching sustainable practices in the case of aluminum packaging recycling.

Considering the studies on packaging waste management, they have addressed the circularity of materials such as plastic, polystyrene, aluminum, and they recurrently reported the need for assessment metrics [52]. Waste management was the largest subcategory in the circular economy, which is explained by the strong concern on reducing the large amount of packaging disposed of in the environment. This end-of-pipe approach is aligned with the circular economy principle of "circulate products and materials".

Generally, waste management covers all aspects of waste, including waste reduction and the collection, transportation, handling, and disposal process. This group of articles analyzed restricted segments, such as a supermarket [53], or broader contexts, such as cities, with an emphasis on packaging's end-of-life. Jang et al. [48] have examined the current efforts on recycling waste by extended producer responsibility (EPR) in cities of South Korea and other countries. In both articles, the authors reveal the urgency of recycling waste. In South Korea, for example, approximately 6.6 million tons of CO2eq could be avoided by material and packaging recycling.

In both situations, packaging redesign and waste management categories, LCA assumed a relevant role as a performance tool. For instance, LCA was used to compare a previous packaging material and the redesigned one. The CE principle "circulate products and materials" was achieved by redesigned packaging that extended product life. Therefore, end-of-life LCA allocation methods gained relevance for driving decisions during packaging design. Niero and Olsen [54] have also used LCA to quantify the environmental performance of aluminum cans in multiple loops.

The LCA method was used in combination with the eco design methodology to identify the life cycle stage that causes less harm to the environment. For instance, Civancik- Uslu et al. [55] argue that in the case of plastic cosmetic packaging, the production stage is a major contributor to environmental impact, due to energy consumption and transportation. These findings rise the following opportunity (Op#).

> *(Op#1) The packaging should be planned in a systemic perspective over the entire life cycle (including production, transportation, etc.) and analyzed in terms of environmental impact on a case-to-case basis to meet circular economy objectives.*

Schmidt Rivera et al. [56] have used a set of circularity indicators and life cycle based indicators to advance the assessment of circular economy strategies in a study of beer packaging and Albuquerque et al. [57] used an alternative approach for LCA named LCC. The results obtained through the LCC concept and externalities indicated an economic benefit and CO2 reduction in their study on the circular economy system of aluminum packaging and tinplate.

> *(Op#2) Life cycle cost (LCC) seems to be an important alternative to reduce costs through out the value chain and an opportunity to complement LCA studies on packaging in the context of circular economy.*

The third principle of circular economy, “regenerate natural systems,” was observed in studies that proposed the development of food packaging from food processing waste to create business opportunities for food industries [58]. Guillard et al. [59] proposed the production of microbial biodegradable polymers from agrofood waste residues. This approach is a way to create an innovative, more resilient, and productive, waste based food packaging economy by decoupling the food packaging industry from fossil feedstocks and allowing nutrients to return to the soil.

> *(Op#3) The following gaps in this research area should be studied: (i) the lack of tools and approaches to properly design and adapt food packaging to food needs; (ii) mathematical simulation, based on modeling of mass transfer and reactions into food/packaging systems. [59]*

A broader perspective on the circular economy was provided by the articles covering the study of supply chains. Meherishi et al. [60] have demonstrated that the circularity of packaging may be independent of the product itself, mainly concerning secondary and tertiary packaging at the pre-consumption stages of the life cycle. Primary post-consumption packaging may also have an independent return flow.

> *(Op#4) Frameworks/methods may be developed to support researchers in circular economy studies. Frameworks must clearly define the following aspects: (i) the function of packaging (primary, secondary, tertiary), the portion of the chain (pre-consumption or post-consumption), and if the reverse flows of the package include the product itself or not.*

Meherishi et al., [60] have also identified three organizational theories that support and drive sustainable packaging supply chain management (SPSCM), the institutional theory, stakeholder theory, and ecological modernization theory. These theories are complementary and have driven the development of a circular economy framework for packaging. Additionally, the study of Batista et al. [61] revealed managerial recommendations that can facilitate the implementation of circular supply chains by other businesses.

> *(Op#5) To improve the circular flows of materials recovered after use, it is recommended to develop and promote collaborations with third-party organizations beyond the boundaries of the focal company's operations, including the cascading of materials into supply chains.*

Category 2, "design", encompassed 21 articles (4.5%) with topics related to packaging design published between 1998 and 2019. An increase in publication was observed in the last five years. The articles brought different perspectives on the design of packaging, such as communication, eco-design education, and project tools.

Starting with Holdway et al. [62], who stated decades ago that being "green" is no longer optional and professionals should seek strategies, practices, and procedures that could promote sustainability in packaging projects. This group of articles was classified in the graphic and structural design phase of the life cycle, describing the strategies applied to packaging design.

The articles that addressed aspects related to the communication subcategory in this category brought graphic design elements, i.e., "ecolabels," to attract consumers' interest [63].

> *(Op#6) Jerzyk [13] argued that manufacturers seek solutions on the market, which are often based on intuition rather than knowledge. This finding reveals an opportunity to approximate the academic community to the manufacturers and developers of packaging.*

Manufacturers have used eco-arguments for their packaging to affect consumers' perceptions and influence their behavior. Buelow et al. [64] argue that there has been little research on the role and adequacy of labeling in driving consumer recycling behavior. Regarding the design practice with a sustainable focus, eco-design methodology stands out. Ma et al. [65] affirm that designers have made efforts to mitigate the environmental impacts of packaging; however, many packaging designs are still far from achieving their sustainability goals.

Regarding design practices, the structural design of packaging (which comprises the shape, texture, materials, and the capability of delivering product packs) was considered a popular way of differentiating products, protecting them from imitation, and adding consumer benefits through improved product delivery and conservation [36]. Nevertheless, nowadays, company managers are looking for alternatives in more sustainable structural projects. In this context, refills show positive results, representing good value, while radically reducing the amount of packaging manufactured and distributed. The customization of packaging design is a recurring subject in the design literature analyzed. In this case, the packaging properties can be improved from several points of view, including functional, aesthetic, economic, and ecological [66].

> *(Op#7) Articles focusing on the design category have emphasized functions, communication, labeling, and structure to achieve environmental requirements. The focus remains on the environmental aspect, so there is opportunity for social and economic investigations.*

Another finding in this group is the evidence on the close relationship between packaging and product. Bucci and Forcellini [35] highlight that the product development process is only complete when the packaging is developed.

Category 3, the "dimensions of sustainability", comprises 45 articles (9.5%), 5 of which were related to the economic dimension, 25 articles addressed the environmental dimension, and 15 addressed the social aspects related to packaging. They were published between 1993 and 2020 with the highest incidence in the last 3 years.

Several approaches have been used to meet the sustainable development goals, including those addressing packaging issues. Such goals consider multiple aspects of sustainability, such as social, economic, and environmental sustainability [67]. The articles that addressed the economic dimension presented themes related to the financial impacts on the packaging recycling chain in the public and private contexts. In Europe, for instance, while each country currently has their own packaging waste management system, there is still a lack of evidence regarding the real costs of recycling and how these costs are distributed among stakeholders [68].

The articles on the environmental dimension of sustainability encompassed themes of packaging recycling, the economic and social impacts related to pre and post consumer waste, and strategies to reduce food waste. Systemic changes in packaging projects can minimize waste and reduce the consumption of materials and energy resources in the packaging production cycle, generating environmental benefits [19]. Therefore, the literature suggests approaches to minimize packaging waste, such as the concentrated efforts from private and public stakeholders to reduce packaging throughout supply chains.

> *(Op#8) Considering contexts such as the health products, in which the elimination of packaging is not feasible, researchers have recommended the creation of global policies on the use and disposal of packaging materials and the education of consumers. [69]*

> *(Op#9) The joint interest of public and private sectors can boost studies on product-service impact and unveil novel alternatives to reduce the environmental impacts of packaging systems. [70]*

The social dimension brought to light problems related to hunger and food waste, legislation, and the social responsibilities of companies. The emphasis on developing packaging that is useful to save food will be important to fulfill the United Nations Sustainable Development Goals. The literature suggests splitting global food waste per capita at the retail and consumer levels and reducing food losses along production and supply chains [71]. As a general rule, the government must play a leading role in improving the policies of waste management regulation [30].

Researchers have adopted a systemic perspective on their studies in both categories and used LCA in environmental investigations. However, in a circular economy, the proposition of new packaging design and indicators to analyze performance along the packaging life cycle were predominant. The environmental dimension was more frequent than the social dimension in both categories, even though findings show that research papers in category 3 tend to bring a more managerial perspective and category 1, a more operational perspective.

Category 4, “life cycle assessment (LCA)”, encompasses 50 articles (10.6%) published from 2001 to 2020. Life cycle assessment is a process of evaluating environmental responsibilities associated with a product by calculating the energy and materials used and the wastes and emissions released over the entire life cycle [72]. Regarding sustainable packaging, it is important to analyze the entire life cycle and to assess multiple impact categories to avoid responsibility shifting. Packaging systems consume natural resources and energy, generate waste, and emit pollutants [73]. Therefore, LCA has become a popular decision supporting tool in packaging design [74,75], as observed in category 2 (design). Life cycle assessment is a method that may be applied alone or, depending on the objective of the analysis, it can be used with the assistance of other artifacts or in specific contexts, such as the circular economy. Discussion in category 1 has illustrated the types of LCA and the tool’s relevance in the circular economy context (see category 1).

Applications of LCA in category 4 articles have been predominantly classified in the filling process, and they are described next. Madival et al. [76] studied the development of new raw materials and applied LCA to compare their impact on the environment. Niero et al. [77] used LCA to analyze a beverage filling process, and Simon et al. [78] studied the impact of collecting bottles after consumption. In this category, comparative studies between material and process cycles predominated [79–81]. The category also brought articles on environmental impacts, losses, and the study of scenarios [75,82,83]. LCA was also applied to test different management approaches. Niero et al. [72] compared the environmental impact associated with different levels of two cradle-to-cradle (C2C) certification requirements.

The life cycle assessment tool is adequate to analyze the environmental impacts caused either by a product, service, or process, and its corresponding packaging (primary, secondary, or of other order).

Managers seeking to reduce the environmental footprint of their products and supply chains face significant informational challenges. Toyota Motor Sales faced this dilemma while reducing the environmental burdens generated by the packaging and distribution of its vehicle service parts and accessories. However, they lacked the information required to quantitatively assess and compare the environmental impacts of different packaging and shipping options and the time or training necessary to conduct the assessments and interpret their results [73]. To facilitate decision making on assessing packaging impacts on the productive process, Toyota Motors Sales has developed a tool to assess the life cycle and cost cycle simultaneously (named EPIC). Therefore, an explicit design goal of EPIC was to create a simple input–output interface that is operable by packaging engineers who are completely unfamiliar with LCA theory and practice. The calculator is intended to be used both internally by packaging engineers at Toyota Motor Sales, and externally by packaging engineers with parts suppliers [73].

Life cycle assessment reveals important factors to be considered to reduce the environmental impact of reusable packaging, such as the transport of the packaging from the users to the industry and the disposal of the solid residues contained in the packaging. Thus, it is important to address the behavior of the users that should use all of the content of the packaging before discarding it and sending it to reconditioning. Other processes that cannot be neglected are the electricity consumption of the reconditioning plant, the heating of the washing water, and the use of solvents [84]. Many environmental concerns lie on the packaging, and life cycle assessment (LCA) is considered one of the most comprehensive and complete tools for assessing environmental profiles [70,85].

Category 5, "marketing", encompassed 56 articles (11.9%) published from 1993 to 2020. The articles revealed different perspectives on packaging marketing, exploring actions related to communication, advertising, the promotion of product sales, and the analysis of consumer behavior.

The role of marketing in society was increasingly debated in the late 1980s and the 1990s, which generated the new concept of green marketing. This concept expanded the role of marketing on sustainability by discussing the sustainability of the marketing mix with green products, green packaging, green logistics, green pricing, and green promotion [86]. Packaging became an attribute to support marketing, offering improved opportunities for better information and communication with the consumer. However, developers must analyze innovative packaging solutions considering their possible increase in costs and influence on the environment [87].

Understanding consumers and satisfying their needs is the basis of marketing theory. Consumers have different needs; therefore, treating them all alike may not lead to their satisfaction. Consequently, it is important to determine who the environmentally oriented consumers are and place “green” products in the right market position [88]. In line with that, sustainable packaging can promote a product brand. The emphasis on the importance of packaging and brand is relevant because studies have recognized packaging’s role in increasing people’s desire to buy products [89].

> *(Op#10) Concerns about the environment and consumers' health are two major reasons for buying food products with ecologically sustainable packaging. [12]*

The articles in category 5 address aspects related to the sale and use phases of the packaging life cycle. At these stages, the package is in contact with the consumer, playing an important role as a silent marketing agent in the retailer.

> *(Op#11) Consumers often make their first judgments about brands and products based on their packages, but brands recognized for following environmental and ethical principles are usually better valued by consumers. [90]*

Packaging’s graphic and structural design provide room for communication with the consumer. Consumers are increasingly concerned about the environmental impact of packaging. Therefore, managers are pressured to adopt eco-friendly packaging for their products. Consumers’ perceptions of eco-friendly packaging are guided by choice of packaging materials and manufacturing processes, as well as by their market appeal [91]. Category 6, “materials”, was the largest in number of articles, with 201 in total (42.6%).

The publications ranged from 1996 to 2020, progressively increasing the volume after 2007. This category was split into the following three subcategories: (i) packaging composition, related to raw materials, with 132 articles; (ii) nanotechnology, with 48 articles; and (iii) new technologies, with 21 articles.

Packaging composition included most of the articles and addressed solutions for food packaging, biodegradable materials, and components to accelerate the polymer biodegradability process. Masmoudi et al. [92] proposed the polyethylene terephthalate (PET) valorization from postconsumer bottles by optimizing the most suitable virgin and recycled PET mixture to be used as food contact packaging. Combinations of these materials were elaborated by extrusion and injection molding using different recycled PET rates.

Many articles have proposed biocomposites from different organic materials, such as vegetable oil-based biopolymers [93]; coffee grounds extract [94]; bird feathers [95]; shrimp residue [15]; sugarcane bagasse [96]; egg white [97] among others.

> *(Op#12) The development of biocomposite materials from renewable resources is an attractive alternative to substitute synthetic and non-biodegradable plastics. [98]*

Nanotechnology is the ability to work on a scale of about 1–100 nm to understand, create, characterize, and use material structures, devices, and systems with new properties derived from their nanostructures. In the nanoscale range, materials may present different electronic properties, which affect their optical, catalytic, and other reactive properties [99]. Nano enabled materials have been widely used in packaging for food products and may contain antioxidant, antibacterial, and antifungal properties, and mechanical barriers. Food packaging is revealed to be a multidisciplinary area that encompasses food science and engineering, microbiology, and chemistry. It has raised interest due to its capability of maintaining the freshness and quality of foods and their raw materials from oxidation and microbial spoilage.

> *(Op#13) With the advances in the packaging industry, packages could be engineered as easy-to-open, resealable, active, as well as intelligent with the incorporation of sensory elements, while still offering the desired barrier properties against oxygen and water vapor. They could be even engineered to provide nutraceuticals to food, or antioxidant, antimicrobial, or antifungal protection to packaged food. [100]*

Another study explored nanotechnology due to its large impact on food packaging applications. Reference [101] used different techniques for synthesizing metal and metal oxide nanotechnology, such as coprecipitation, hydrothermal synthesis, microemulsion, microwave assisted synthetic methods, and others.

Moreover, the articles selected in the "new technologies" subcategory addressed innovative solutions for bioplastics and new materials, new technologies for safety, conservation, increased food shelf life, and the use of sensors.

> *(Op#14) The collaboration between the bioplastic packaging producers and the product manufacturers should, therefore, improve product functionality and innovation in packaging technologies. [102]*

Innovation activities for food packaging have gradually expanded towards the development of intelligent packaging. This evolution reflects the emerging need for new and efficient ways to diminish business processes, solve supply chain safety and quality issues, and reduce product losses [29]. Food intelligent packaging (IP) technologies are reviewed with a particular emphasis on the possibilities of radiofrequency identification (RFID) and surface acoustic wave (SAW), which are technologies for developing the food IP concept. Passive RFID and SAW technologies are the most promising ones to achieve a food IP that can wirelessly communicate the food quality to the different agents of the food chain [103]. Most articles on materials have been sorted under the "transformation of raw material"

life cycle stage. Articles in this category address topics related to the composition of new materials, both nanotechnological and innovative. Moreover, some review articles explored metal based packaging materials that provide superior barrier properties, which are widely used in food packaging. Metals such as aluminum, tinplate, tin free steel, stainless steel, as well as metal based packaging material in both rigid and semi rigid forms, such as cans, foil wraps, and retort pouches, are the most used for food packaging applications [104].

Active packaging is a solution in which the packaging, the product, and the environment interact [105]. The following active packaging systems are used in the food industry: oxygen, carbon dioxide, ethylene scavengers; carbon dioxide emitters; odor emitters and absorbers; relative humidity regulators (water content in the packaging atmosphere); antibacterial substances and antioxidants [105]. The largest group of emitters consists of antimicrobial substances inside the packaging. These substances may be added to packaging in different formats, such as sachets or mats with volatile antimicrobial compounds; active substances embedded in the polymer structure; active substances applied to the polymer surface; active substances immobilized on the polymer using ionic and covalent bonds; packaging films with antimicrobial properties (e.g., chitosan-based films) and edible food coatings.

*(Op#15) Due to the growing interest of consumers in consuming fresh products with extended shelf life and controlled quality, manufacturers must provide modern and safe packaging. Active packaging is a promising solution for this.*

Category 7, “reverse logistics (RL)”, encompassed nine specific articles (1.9%). They were published from 2013 to 2020 and explore packaging used as new raw material and studies about their logistics process. The articles in this category brought different perspectives on packaging RL, such as decision making tools, regulatory matters, agreements, and packaging design for RL. They also address other packaging classes, such as primary, secondary, and tertiary, at different product life cycle phases.

As RL can occur at diverse stages of the product life cycle, Silva et al. [106] studied the advantages of replacing the packaging of an earphone device with a creative returnable packaging at the “pre-consumption” logistics phase of the earphone manufacturing. Lagarda Leyva et al. [107] studied the RL of tomato pesticide packaging at the “post-consumption” phase of the pesticide packaging (end-of-use).

These analyses shed light on the fact that RL is a broad field, and that packaging RL is just a part of it. This observation reinforces the findings from category 1, circular economy. It highlights the parallelism between the product life cycle and its packaging life cycle and the independent reverse flows that the product and its package must take during post-consumption (see Op# 4 and Meherishi et al. [60]. RL processes may comprise primary, secondary or tertiary packaging. Therefore, scholars must delimitate the scope of investigation when addressing packaging RL.

The decision making methods in this group of articles ranged from multicriteria techniques to simulation, using different approaches, such as mathematical techniques and systems dynamics. Couto et al. [108] applied an objective function to support decisions on the geographical location of screening and valorization centers for packaging, highlighting parameters that influence the sustainability of these sites. Additionally, Lagarda Leyva et al. [107] used systems dynamics to simulate the RL process.

(Op#16) Decision making through mathematical methods leads to fewer costs, time, and involved risks when compared to the real implementation of RL packaging. Therefore, mathematical models can be used to analyze the supply chain.

Concerning multicriteria decision tools, Li and Huang [109] used the analytic network process (ANP) to decide the geographical location of recycling centers and garbage factories. As an advantage of ANP, the criteria are analyzed interdependently. Therefore, ANP can reflect the overall situation of the RL system. In other words, it will reflect the fixed and variable costs and ultimately find the best facilities' location and construction size, as well as the flow of each link. Thomopoulos et al. [16] applied multi-criteria reverse engineering (MRE). MRE has arisen from the interaction of advances in mathematics and shifts in social demand.

In their study about returnable transport packaging (RTP), which is a part of the broader concept of (RL), Yusuf et al., (2017) confirm the positive business performance results of RTP. Nonetheless, despite the advantageous nature of packaging RL, the authors also highlight financial constraints and the drawback of packaging wear and tear due to reuse. These constraints are barriers to adopting RTP implementation, mainly by small and medium companies, based on data drawn from developed countries [110].

Another perspective that emerged in this group of articles was the need to design packaging for RL purposes to address the second principle of circular economy, namely "keeping products and materials in use". On the one hand, Silva et al. [106] focus on the type of "returnable packaging project" itself for comparison purposes, while Zouari [111] focuses on the "design methodology of the package" through the combination of eco design, resource commitment, and RL. Zouari [111] argues that collaboration along the process leads to positive and better results. His findings show that a cardboard Caixa de pizza 35, 40 e 45cm based packaging submitted to eco-design requirements and a structured resource commitment positively affects RL. However, the stakeholders analyzed did not consider the entire life cycle of cardboard production, which might consume more energy than other materials.

(Op#17) The performance analysis of new packages for RL should be conducted together with techniques such as life cycle assessment (LCA) to compare the scenario with new and former packages.

In this group of articles, the circular economy was frequently mentioned in different situations, since RL is a circular economy strategy. Guarnieri et al. [47] studied the Brazilian sectoral agreements for packaging RL in search of opportunities for the circular economy.

The authors concluded that the agreement development was guided by circular economy principles, although the concept was not mentioned in the agreement text.

Category 8, "supply chain", encompassed 29 publications (6.1%). They ranged from 2003 to 2020, exploring themes of the supply chain context. The articles studied the feasibility of using returnable packaging in the supply chain. They analyzed strategies to reduce the environmental impacts caused by the movement of goods and raised questions about the effect of packaging on the logistical process.

A company's supply chain needs to ensure that the right product will be delivered at the right time and cost. It also still needs to consider an additional responsibility of fulfilling the environmental requirements [6]. The packaging system's design has a major impact on the environment, but the impact is not easily assessed due to the complex coupling between package design, logistics costs, and environmental impact [112].

> *(Op#18) Storage space utilization and conveying information are important in packaging design due to their impact on packaging logistics and other aspects of the supply chain system.*

In this group, quantitative and qualitative strategies were used to answer the research questions raised in the articles. Bortolini et al. [113] present an integrative mathematical model with a deep focus on the role of packaging containers for fruit and vegetable distribution, considering reusable and disposable alternatives. These alternatives may coexist; therefore, the decision maker may choose among a supply network based on disposable packaging containers, reusable packaging containers, or their combination. The model proposed is useful for supporting such strategic decisions.

Due to the complexity brought by the supply chain, some solutions can arise via the approximation of one or more strategies. For instance, Gardas et al. [114] present fourteen critical success factors (CSFs). The interpretive structural modeling (ISM) approach was applied to explore the mutual influence between the identified CSFs. The ISM methodology was supported by the total interpretive structural modeling (TISM) approach to strengthen its interpretation. Furthermore, to identify the factors with high driving power, the “Matrice d’Impacts Croisés Multiplication Appliqués à un Classement” (MICMAC) analysis was employed. Wang et al. [115] present an alternative to contribute to the complexity of the sustainable supply chain via decision making trial and evaluation laboratory (DEMATEL). Using DEMATEL, the authors have extracted the interrelationship between multiple factors in a problem. DEMATEL is a multicriteria decision making instrument that allows converting a qualitative design into quantitative analysis.

It is important to emphasize that, in addition to the packaging residue, goods movement contributes to the generation of environmental impact caused by CO2 emission into the atmosphere, loss of goods, or design inadequacies between the packaging and the product. Hence, changing the packaging system design and logistical system may reduce these impacts. The articles selected for this category comprise all packaging life cycle stages. Moreover, it is important to reiterate that the supply chain involves all the flows necessary for the development, manufacturing, commercialization, use, and disposal of the product and its packaging.

Lastly, category 9, “sustainable practices”, encompassed 41 articles (8.7%). They ranged from 2001 to 2020, and 23 were related to recycling practices; 13 articles addressed waste reduction, and 5 addressed packaging reuses. Sustainable practices still need to be improved to reduce waste further, increase recycling and reuse, and manage waste efficiently [19]. In this group, practices such as recycling, reducing, and reusing were explored. Recycling plastics is motivated by the need for closing material loops to preserve natural resources when moving towards a circular economy. It is also motivated by the problems derived from plastic scrap in oceans and lakes. The packaging industry uses the highest number of plastics; hence, plastic waste is predominated by packages [116].

The articles that address waste reduction practices seek solutions to decrease the use of materials and renewable sources, as well as to minimize environmental impact. An experiment conducted with 218 consumers demonstrates that non environmentally conscious consumers chose the over package competing product because the non overpackage product seems less safe or practical [117]. One approach suggested to address these concerns is “zero waste”. However, transforming today’s over consuming activities into zero waste is still challenging [34]. There have been many actions to eliminate packaging waste through open dumping and burning, landfill, incineration, etc. However, little attention has been paid to reuse, even though it is the simplest way to reduce waste.

Reuse is an essential solution, which should be considered before any other approaches [118]. Nevertheless, packaging reuse is limited in health and food segments. The use of solid packaging waste in sustainable construction has received much attention due to the lower cost of waste, along with the saving of space in landfills [119]. Nevertheless, reusing is more difficult, even in this case.

Most of the articles address the post-use life cycle phase. Sustainable practices are more related to waste management, covering three dimensions (economic, environmental, and social). Few articles addressed the raw material transformation, graphic and structural design, packaging manufacturing, and filling process phases.

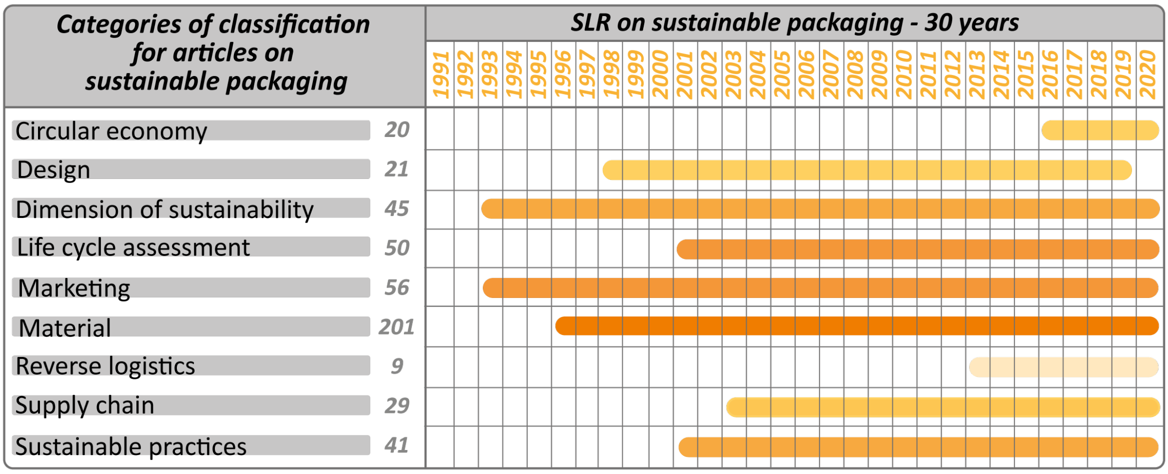
Agrochemical packaging must be decontaminated before its recycling. Such reprocessing can allow large amounts of these materials to feed the production cycle. On the other hand, plastic recycling in the agricultural sector presents financial, managerial, and technical barriers [120].

Lu et al. [10] expands the research area to e-commerce and confirms the importance of user preference in overpackaging solutions. The authors argue that consumers prefer technical solutions to optimize the packaging strategy. However, they have a low preference for material improvements. Consumers generally believe that technology can improve efficiency, enhance quality, and avoid unnecessary waste, fundamentally reducing overpackaging. [10].

The overarching aim of the circular economy is to maintain the value of products, materials, and resources for as long as possible, and the reuse of packaging can play an important role [121]. A method to collect data on reusable packaging was applied in the Italian context. The authors identified 38 types of packaging currently reused in the Italian territory [121], resulting in a preliminary qualitative and quantitative assessment of the packaging reuse practice.

The categorization into coding units allowed answering RQ3. As listed in each of the last nine categories under the symbol (Op#), the opportunities ranged from strategic actions, designer tasks, and product management processes towards themes such as integration among interdependent stakeholders and collaboration. The opportunities were not restricted to this list, as they were mentioned throughout the rest of the article. Figure 10 describes the distribution of articles per year, and the shades of orange represent the number of articles in each category.

**Figure 10.** Distribution of articles per year in each category




The larger the number of papers in categories, the darker is the intensity of orange color

**Fonte:** The authors

The analysis of Figure 10 shows four clusters. Cluster 1 includes articles on the dimensions of sustainability, materials, and marketing that have predominated over the years with publications since the 1990s. Environmental issues play a central role in this cluster as a common ground for all categories, boosting the development of new materials. Cluster 2 includes life cycle assessment, supply chain, and sustainable practices. These themes have evolved significantly after 2000. LCA was found to be a tool of wide application to compare materials' performance, develop supply chains, and test the efficiency of sustainable practices.

LCA has proved to be relevant for the analysis of the circular economy and RL, the two last categories in Cluster 3. There are some similarities between content in category 1 (circular economy) and category 3 (dimensions of sustainability). Both categories emphasize topics on the environmental, social, economic financial, and waste management dimensions. Circular economy studies have involved more innovative solutions to avoid waste generation, while articles classified as sustainability studies presented a more strategic and managerial perspective on the packaging system development. RL is part of the circular economy process. Hence, a cluster with these two categories was created.

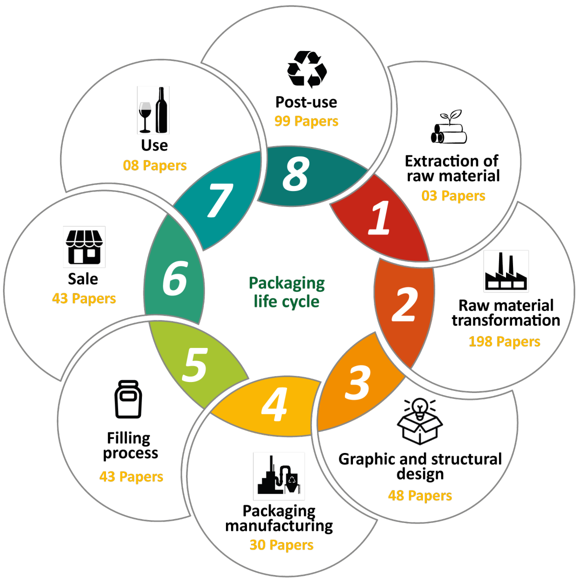
The design category has a different approach, which was included in Cluster 4. The group of selected articles showed relatively few publications over the years, which suggests an opportunity for deepening the investigation on this topic.

Many combinations of categories are plausible due to the interdependencies existing among them. Next, to answer RQ1 and RQ2, the authors have analyzed the units of context presented in Sections 3.2.3 and 3.2.4. The purpose was to explore interdependencies to find other meanings to the vast content.

### *2.3.2.3 Packaging Life Cycle Stages as Context Units*

The search for meaning inside content analysis advocates for using context units. The context unit "packaging life cycle" was used to answer RQ1. We have defined "sustainable strategies" as the techniques, methods, tools, or processes used by researchers to leverage the sustainable condition of packaging systems. Our aim was not to judge the strategy's efficiency; rather, we intended to create a logical repository of intuitive and easily accessible information. Thus, the packaging life cycle stages were chosen as a reference due to the systemic view they provide, which is necessary for designing sustainable systems. The articles were analyzed and reclassified into one of the eight life cycle stages (Figure 11) based on their contribution to that stage. Considering the packaging as something created and developed as a product, it can be defined by its life cycle. The eight stage model (Figure 11) was adopted from models proposed by several authors [54,70,79,82,122–126].

**Figure 11.** Classification of the articles according to the packaging life cycle stages




**Fonte:** The authors

Supplementary Material—S6 describes the sustainability strategies presented in each article, followed by their classification in a life cycle stage. The first strategy, "definition of sustainability agendas to the commitment of raw material leading companies" by Hillier et al., [127] addresses strategic actions for the extraction of raw materials. Therefore, it was reclassified in the life cycle stage as "extraction of raw materials". The second strategy, "search for a new composition of packaging raw materials" as presented by Iahnke et al. [98] addresses the transformation of raw materials, and it was classified in the life cycle stage as "raw material transformation". The same analysis was conducted for all the articles.

Context units are important strategies to unveil the complexity and bring meaning to the content on sustainable packaging. The professionals and researchers from every industrial segment (food, chemical, raw materials and energy) interested in more details about the knowledge gathered in this SLR can explore the information using the life cycle stages as a reference, according to their content interests.

Although packaging seems simple from the structural point of view, it is highly complex from the systemic point of view. The design of sustainable packaging demands a thorough and time consuming information search.

Moreover, the reclassification revealed some patterns. Research efforts mainly concentrate on stage 2, raw material transformation, and stage 8, post-use. This demonstrates that researchers have been motivated to research these topics due to the urgency imposed by the huge environmental impact of packaging. Furthermore, the food industry has analyzed the composition of raw materials for packaging, technologies, and intelligent packaging. The reason for this leadership is portrayed by Deshwal et al. [128] when they discuss various health and environmental issues concerning food packaging. Although opportunities for food packaging were more frequent in Section 3.2.2 (see Op#13, 15), other frequently regulated packaging segments include beverages, pharmaceutical, and medical.

The existence of many articles classified in the last life cycle stage (post-use) does not necessarily mean that researchers were not concerned about giving a systemic perspective to their research. On the contrary, studies in this group use methods that provide a systemic perspective, such as systems dynamics, different types of life cycle assessment tools (LCC, LCS), RL optimization algorithms, etc. Nevertheless, opportunity 1 (Section 3.2.2) showed that researchers must systemically understand packaging regarding packaging function, supply chain link, and the package and/or product flows.

The amount of packaging polluting the environment may indicate that the reality is different from research, as reinforced by Jerzyk [13]. The articles classified in life cycle stages 3, 4, and 5 apply methods to compare environmental solutions in the filling process, manufacturing, and design operations. The changes made to the different packages and other variables tested in such investigations reinforce the perception that current packaging designs were not developed to facilitate pre-consumption and post-consumption sustainable practices. Moreover, eco-design, design for sustainability, and cradle-to-cradle are sustainable design methods not specific to designing packages. The life cycle stages with fewer articles were the extraction of raw material and use.

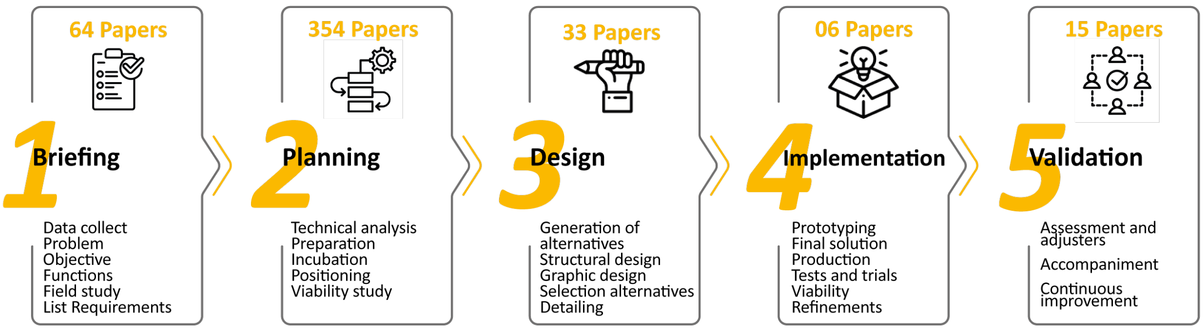
> (Op#19) Researchers should emphasize formal methods to develop tools that support packaging professionals to integrate the information from life cycle stages in the phases of packaging design.

As expected, marketing articles were distributed between the "use" and "sale" life cycle stages. More discussion on contents may be observed in Section 3.2.2 (marketing).

### *2.3.2.4 Packaging Design Phases as Context Units*

The design phases were used as context units to answer RQ2. Therefore, the five phase model (briefing, planning, design, implementation, and validation) was adopted from the models proposed by several authors [1–3,129–133]. Figure 12 shows the reclassification of publications according to the phases of the packaging design. Table 2 explains the structure of the analysis.

**Figure 12.** Classification of the articles according to the packaging design phases.




**Fonte:** The authors

**Table 2.** Classification of procedures that support the practice of packaging professionals according to design phases.

| **Packaging design phases** | **Examples of tools, methods, practices, and data to support packaging professionals regarding circular economy and sustainable packaging** |
|---|---|
| Briefing | Use of structural, graphical, and informational cues [85] |
| | Analysis of sectoral agreements and regulations by packaging managers [43] |

| | |
|---|---|
| | Design of the supply chain network [108] |
| Planning | Definition of raw material for packaging such as non-biodegradable plastics; biocomposites from vegetable oil-based biopolymers |
| | Use of nanotechnology to extend product shelf life, improve biodegradability, or due to other demands (ex., food packaging, health packaging, etc.) |
| | Use of new technologies for packaging sustainability (active systems, intelligence) |
| | Use of system dynamics to plan packaging's end of life [102] |
| | Analysis of sectoral agreements and regulations by the packaging team [43] |
| | Use of algorithm for reverse logistics optimization [30] |
| | Use of LCA to analyze the impact of production during the project stage [137] |
| | Identify raw material suppliers committed to packaging sustainability [122] |
| Design | Strategy for private labels [34] |
| | Visualization tool, which focuses on different parts of the participant's view and experience of the development process in the project [5] |
| | Project of eco-labels using eye-tracking glasses [58] |
| | Requirements for a better packaging design/redesign;<br>Technical improvements; Attention to external demands, Management practices [56] |
| | Use of life cycle assessment for comparison of the performance of packaging materials [139] |
| | Use of best-worst scaling experiment in packaging project [7] |
| Implementation | Use of cost analysis techniques to implement packaging productive systems [52] |
| | Use of best-worst scaling experiment in packaging project [7] |
| Validation | Consumer's perception of eco-friendly packaging: in terms of packaging materials, manufacturing technology, marketing appeal [86] |
| | Routine of tests of innovative packaging systems [101] |

**Fonte:** The authors

The organization of Table 2 was conducted based on the description of the tools, methods, and practices from articles described in Supplementary Material—S7. The information on the procedures applicable to sustainable packaging development was consolidated in Table 2. The reasoning underlying the reclassification is explained next. The first phase, "briefing", concerns the definition of requirements from all stakeholders. Then, packaging managers and team members must analyze the packaging context of usage, interview users, understand the needs to define the objective of the project, the main functions, and elicit requirements. Therefore, in the first line, "briefing", the practices, methods, and tools that emerged from the analysis made in Section 3.2.2 were classified. The aim was to create a logical repository of information with easy and intuitive access, following the design phases.

This literature analysis indicated that 13% of the articles are associated with the "briefing" phase. Information on sectoral agreements, supply chain network analysis, and structural/graphical cues are important data types for the briefing process. Wikström et al. [136]

highlight that the briefing process is critical because the design objective is formulated and communicated to the design team in this step. Packaging managers should develop clear briefings because the influence of ecological design elements on preferences strongly depends on the consumers’ level of environmental concern [137].

Therefore, professionals should collect data that support the problem identification, the definition of functions, adopt sustainable objectives for the packaging project [138,139], conduct field studies to guide their actions [51,140] or analyze the appropriate requirements [27,141].

The present literature review demonstrated that 75% of articles are associated with the “planning phase”. This is explained by the fact that materials and packaging manufacturing processes are chosen in the planning phase [39,142], in addition to the technical and feasibility analysis [134,143]. However, most articles are in the food packaging field. Usually, the choice of a packaging that best suits fresh food requirements is driven by issues such as cost, shelf life, safety, practicality, and environmental sustainability [134].

The “design” phase constitutes 6% of the articles, mainly on structural design and graphic projects [35,135,144]. Eco-labels, visualization tools, requirements, LCA, and best-worst scaling are procedures that can support professionals in the design phase. Opportunities through refills and techniques for comparing solutions in the design phase were discussed in Section 3.2.2 (design) and Section 3.2.3.

Some procedures may be used in more than one design phase, since the objective of the application may change based on the purpose of the phase. Moreover, phases 3, 4, and 5 must be conducted iteratively, seeking to optimize the packaging development. The implementation phase (phase 4) is composed of 1% of the articles and comprises the final packaging solution, prototyping, tests, manufacturing trials [145,146], and viability [147]. The viability (phase 5) encompassed 3% of the articles. It addresses the monitoring of the packaging in the market [106,111,148] and provides information for possible adjustments in the next production cycle.

Based on the classification according to the packaging design phases, our results show how the tools from the literature may support designers in designing sustainable and circular packaging (Table 2).

Section 4.1 and Table 3 expand the discussion on design phases with insights from the literature and guidelines for professionals.

**Table 3.** Insights and guidelines for professionals in the multiple areas of packaging design

| **Triangulation DP –** CAT and LCS | **Insights** | **Guideline description** |
|---|---|---|
| Briefing – circular economy (CE) and post-use | Briefing is more than the scope or requirements demanded by stakeholders for the packaging | Understand all stages of the packaging life cycle and the critical intersection points with the product life cycle. |
| Briefing – sustainable practices and post-use | Briefing is the right moment to consider eliminating packaging | Analyze the packaging life cycle and promote the reduction or non-use of packaging within the supply chain. Understand the packaging needs of each product. |
| Planning – dimension of sustainability and post-use | Sustainable education for packaging is as dependent on public policies as they are dependent on clear actions from the packaging planning phase | Identify global policies for the use and disposal of packaging materials and consumer education from the packaging planning phase. |
| Planning – life cycle assessment and post-use | What is not measured over the entire packaging system cannot be improved | Observe, collect, and analyze demands from all stakeholders throughout the life cycle.<br>Good integration between packaging and its contents, i.e., start with planning and must filling process and logistical specifications. |
| Planning – material, extraction of raw material, and transformation | It is increasingly necessary to include in the packaging planning phase the search for recent materials and technologies to replace polymers | Consider the use of biocomposite materials from renewable resources to replace synthetic and non-biodegradable plastics. |
| Planning – reverse logistics and filling process. | The type of waste and impact potentially generated by a package that already exists on the market is an important reference to start planning a new package | Start the planning at the packaging's end of life to avoid a similar impact.<br>Promote reverse logistics for new packaging and use techniques such as life cycle assessment (LCA) to compare the scenario with new and old packaging. |
| Design – design stage and graphic and structural design | Graphic and structural design are more than creative actions. They must integrate the information gathered in the briefing and planning phases | Optimize existing designs or create lean packaging. Reduce the use of materials (paints and special finishes), take advantage of useful areas, and reduce the number of scraps. |
| Implementation – supply chain and packaging manufacturing | Implementation is more than manufacturing the packaging. It must integrate information gathered in the previous phases to avoid negative impact in the subsequent phase | Optimize packaging use along the supply chain. Understand impacts on packaging logistics and other aspects of the supply chain system. |
| Validation. – marketing, sale, and use | The packaging communication space can be better exploited to convey information about disposal, type of material used, and consumer awareness | Prioritize prime spaces on labels and packaging to include sustainable information.<br>Highlight information about the materials used in the packaging, and their correct disposal. |

**Fonte:** The authors

## 2.4 TRIANGULATION OF CATEGORIES AND THE TWO UNITS OF ANALYSIS PRACTICAL IMPLICATIONS

The triangulation in figure 13 is supported by the degree of association existing between the category (CAT), the life cycle stage (LC), and the design phase (DP). We have used the objective of each design stage as a guideline for triangulation.

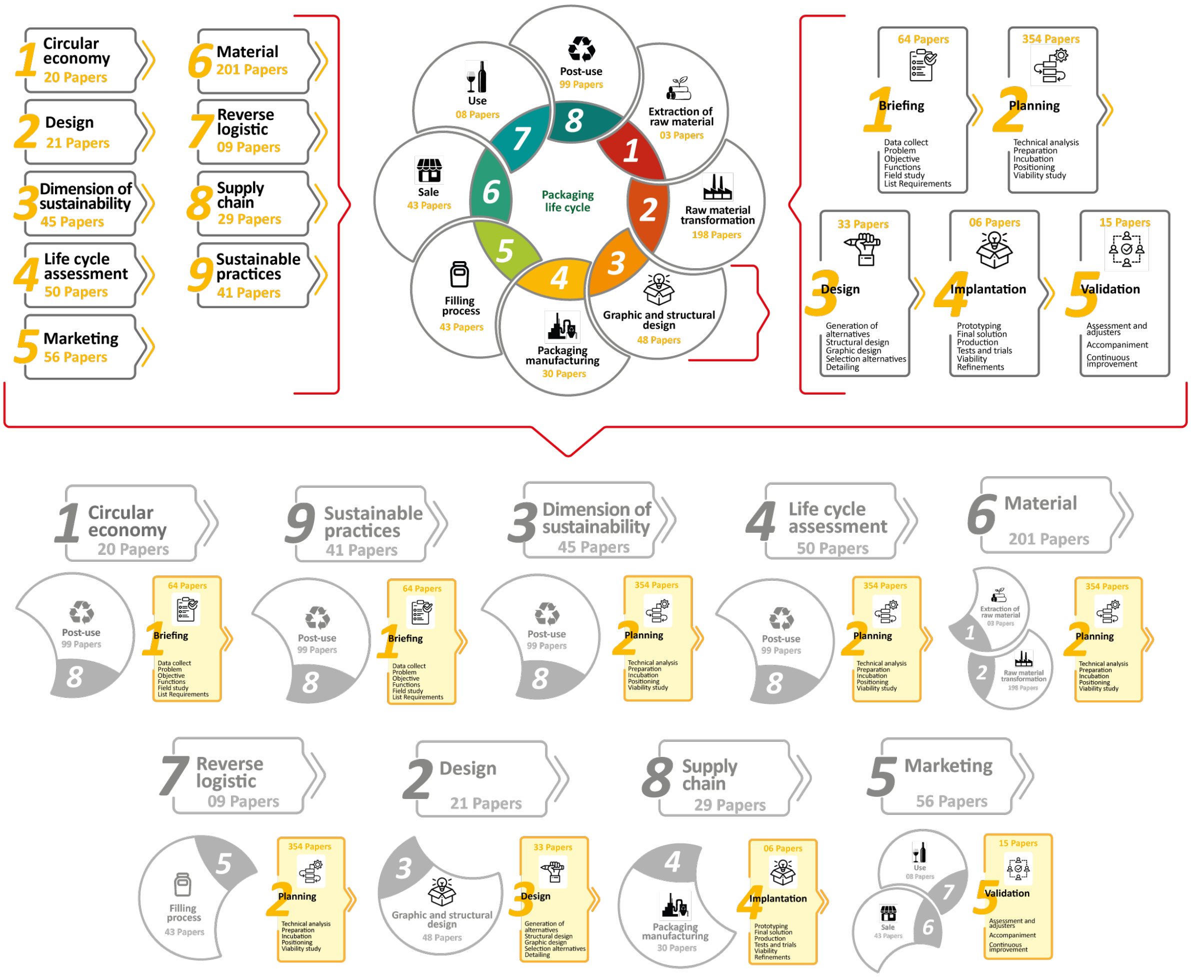
The lower part of figure 13 simulates the reasoning of a packaging designer. Therefore, the emphasis is on the packaging design phases (1—briefing to 5—validation). While progressing through the design stages, designers may have to go through the eight life cycle stages systematically and the nine thematic categories to gain insight into their creative process.

In this proposition, the nine categories of information were arranged considering the objective of the design phase. For example, the objective of the briefing phase is to define project specifications. Therefore, the designer must collect demands from all stakeholders over the entire life cycle. With the purpose of "avoiding waste generation", the designer must bring the "principles of circular economy" as a guideline or "environmental demand" during the briefing phase. Consequently, the dotted line in the lower part of figure 13 shows the relationship among briefing, post use, and circular economy.

The elements in figure 13 may be arranged in another order or combination, depending on the nature, purpose, or degree of innovativeness of the sustainable packaging under design.

The framework in the lower part of figure 13 presents at least three main benefits. First, it creates a systematic procedure that highlights the need to incorporate the life cycle as a systemic perspective, following each phase of the packaging design process. Second, the nine category repository organized via this SLR (Section 3.2.2) provides the contente corresponding to each life cycle stage. Third, procedures from Table 2 (Section 3.2.4) provide the methodological approaches necessary for the packaging creation and assessment.

**Figure 13.** Triangulation among the categories and the two units of context




**Fonte:** The authors

### 2.4.1 Insights and Guidelines for Practitioners

Finally, Table 3 presents insights and guidelines for packaging professionals. They are the different types of specialists who participate in the project activities over the entire sustainable packaging life cycle process. The analysis was guided by the triangulation among design phases (DP), the life cycle stages (LC), and the categories (CAT) from the lower part of figure 13. We aim to illustrate how insights may arise from the framework application; therefore, the authors do not intend to be exhaustive in Table 3. Guidelines were proposed based on the findings from former sections and the articles of this SLR.

For example, considering the rationale of triangulation between briefing, circular economy, and post use, the following insight arises: “Briefing is more than the scope or requirements demanded by the stakeholders for the packaging”. Regarding the literature analyzed in this

SLR, the following guideline arises: “designers must understand all stages of the packaging life cycle and the critical intersection points with the product life cycle.” The triangulation flow (Figure 13) exemplified in Table 3 may guide the collaborative discussion among professionals, since it encompasses multiple aspects of the design phases. The framework may be used for (i) defining types of trustable information to be elicited and (ii) to support decision making. The proposed framework can be a starting point for developing a tool centered on repositories that support professionals.

This SLR has revealed four categories of opportunities for investigation. The first category for designers and researchers is “new methods, tools, and packaging performance” (op#1, 2, 3, 4, 7, 16, 17 and 19 in Sections 3.2.2 and 3.2.3). The second category “collaboration for innovation in the packaging supply chain” (op#5, 6, 9 and 14) may concern all the lifecycle stakeholders. The third category is “policies, education and consumer perception” (op#8, 10 and 11) and the fourth category is “materials and technologies” (op#12, 13 and 15). All the categories are interdependent and experts inside the academy, government, or industry may find an occasion to develop innovative solutions to fill these gaps.

## 2.5 FINAL CONSIDERATIONS

The academic literature comprises some systematic literature reviews on the packaging subject. Nevertheless, our study was designed differently with a reduced keyword search to recover the largest number of publications on sustainability and packaging. The purpose was to cover 30 years of investigation to gain a broad perspective of what has been researched so far.

The methodological strategy used in this SLR brought benefits and limitations to this SLR. The main benefit was to provide an updated repository of information to support packaging researchers and professionals. We analyzed the content of the 472 articles to answer RQ 1, which was as follows: “What has been discussed, in the literature, about sustainability strategies applied to the packaging life cycle?”. An analysis of the literature revealed nine categories of themes organized in four clusters. The first cluster included the topics dimensions of sustainability (9.5%), materials (42.6%), and marketing (11.9%), published from the 1990s onwards. The second cluster included articles published ten years later (2000) regarding life cycle assessment (10.6%), supply chain (6.1%), and sustainable practices (8.7%). The third cluster is the most recent (2013 onwards), and it addressed reverse logistics (1.9%) and circular economy (4.2%), and the fourth cluster, design (4.5%), was quite different from all other clusters in its characteristics. The design cluster presented only one topic and the articles were published after 1998 at a very low rate. The impressive number of articles on the materials topic, on the one hand, has demonstrated the strong concern of researchers on reducing food packaging environmental harm and making it safe for human health. On the other hand, these findings may be important references for different industrial segments on new raw materials, nanotechnology, and smart packaging. The limitation of the content analysis was the difficulty of the summarization of a large body of information from all the articles retrieved. Therefore, we have provided some Supplementary Materials and appendices to cover this restriction.

The units of context proved to be valuable to answer RQ 2, i.e., "how has the literature supported packaging professionals' practice in the context of the circular economy and sustainable packaging?". The objective of each phase of packaging design (briefing, planning, etc.) guided the identification of procedures, methods, and tools, including mathematical approaches and managerial and decision making alternatives. The tools were either for planning the packaging system as a whole (frameworks for designing circular economy, reverse logistics, and supply chain processes) or procedures for designing a specific packaging device.

Likewise, the content analysis highlighted the relevant role that LCA plays in performance analysis in all stages of the packaging design or the system's performance as a whole. It is important to mention that LCA's relevance is also growing in the corporative background, mainly due to managers' ever increasing interest in environmental, social, and governance (ESG) performance strategies. The articles retrieved in this SLR, until 2020, did not mention this perspective. The low number of articles in the "design" category suggests an opportunity in this topic, especially concerning specific methods for designing sustainable circular packages.

Regarding RQ 3, "what research opportunities can emerge from analyzing current literature on sustainable packaging?", we have identified opportunities regarding (i) the development of specific frameworks for packaging; (ii) popularization of tools; (iii) collaboration (private, public, academy) and multidisciplinary teams in packaging development; (iv) new policies; (v) boosting of the social dimension of sustainability; (vi) reinforcement of consumers' and manufacturers' responsibility; (vii) creation of drivers for packaging sustainability; (viii) popularization of technologies and strategies, such as eco-labeling; (ix) reinforcement of communication on environmental properties of packaging to promote sales and adequate disposal; among others.

We have observed that the search for solutions to the problems of sustainable packaging focuses on new materials, new technologies, and analytical methods for verifying the performance of packaging, among others. Fortunately, there already is a concern to treat the packaging project systemically, following the example of mathematical approaches and other applications on circular economy, supply chain, and reverse logistics. Such systemic approaches are still complex to organizations' routines, and they should be simplified for popularization purposes soon.

Given that the categories studied present some overlap, the challenge is the proposition of approaches that integrate these categories via the combination of the best practices developed in the individual themes. Considering this set of articles, we have observed that methodological structures to guide sustainable packaging design have not evolved to the same degree as other categories analyzed. Therefore, there is an opportunity to revisit the packaging design steps to incorporate the tools and practices mentioned in the categories found in this review. Step-by-step methods are always important guides to support the practice of professionals involved with sustainable packaging, but it is also necessary to improve the education of new professionals in academic courses.

Therefore, going beyond the coding units of the SLR content analysis, we have used context units to propose a framework based on the triangulation of the packaging life cycle stages, the nine categories, and the design phases. At the same time, the framework provides an understanding of the relationship between packaging design phases, life cycle stages, and an in depth view of the sources of information for each step of the packaging life cycle. Hence, we believe this framework is a preliminary reference for creating insights, identifying opportunities, and developing procedures for sustainable and circular packaging methodologies.

**Supplementary Materials**: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su14116727/s1, S1 Classification of article by year; S2 Areas of knowledge; S3 Keywords RSL; S4 Country list; S5 Classification of articles_categories_life cycle_Design stages; S6 Tables categories for classification of the articles analyzed and S7 Packaging methods.

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R.M.S.; I.C.d.P.; M.E.S.E.; investigation, R.M.S.; I.C.d.P.; M.E.S.E.; resources, R.M.S.; I.C.d.P.; M.E.S.E.; data curation, R.M.S.; I.C.d.P.; writing—original draft preparation, R.M.S.; I.C.d.P.; writing—R.M.S.; I.C.d.P.; M.E.S.E.; review and editing, R.M.S.; I.C.d.P.; M.E.S.E.; visualization, R.M.S.; I.C.d.P.; M.E.S.E.; supervision, I.C.d.P.; M.E.S.E.; project administration, I.C.d.P.; M.E.S.E.; funding acquisition, I.C.d.P.; M.E.S.E. All authors have read and agreed to the published version of the manuscript.

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**Appendix A:** Links of all the articles returned in SLR and links of the articles/phase of the SLR protocol. Link of all the articles returned in the sources investigated—identification phase: https://drive.google.com/drive/folders/11YPAVP9_uTQprSvZAxfIjQNnMEgTsOjM?usp=sharing (accessed on 1 May 2022). Links of articles selected—selection phase: https://drive.google.com/drive/folders/1iM9ee_n_Rn83RDhv3OcdV0fZgXroDLnM?usp=sharing (accessed on 1 May 2022). Links of excluded articles—eligibility phase: https://drive.google.com/drive/folders/1i528APijnrbQzmn0lM0pGfAwkQyytkfT?usp=sharing (accessed on 1 May 2022). Links of articles considered for the analysis—inclusion phase: https://drive.google.com/drive/folers/13Nn5mvIFoVt6rsEhuhwguE_6STYOI442?usp=sharing (accessed on 1 May 2022).

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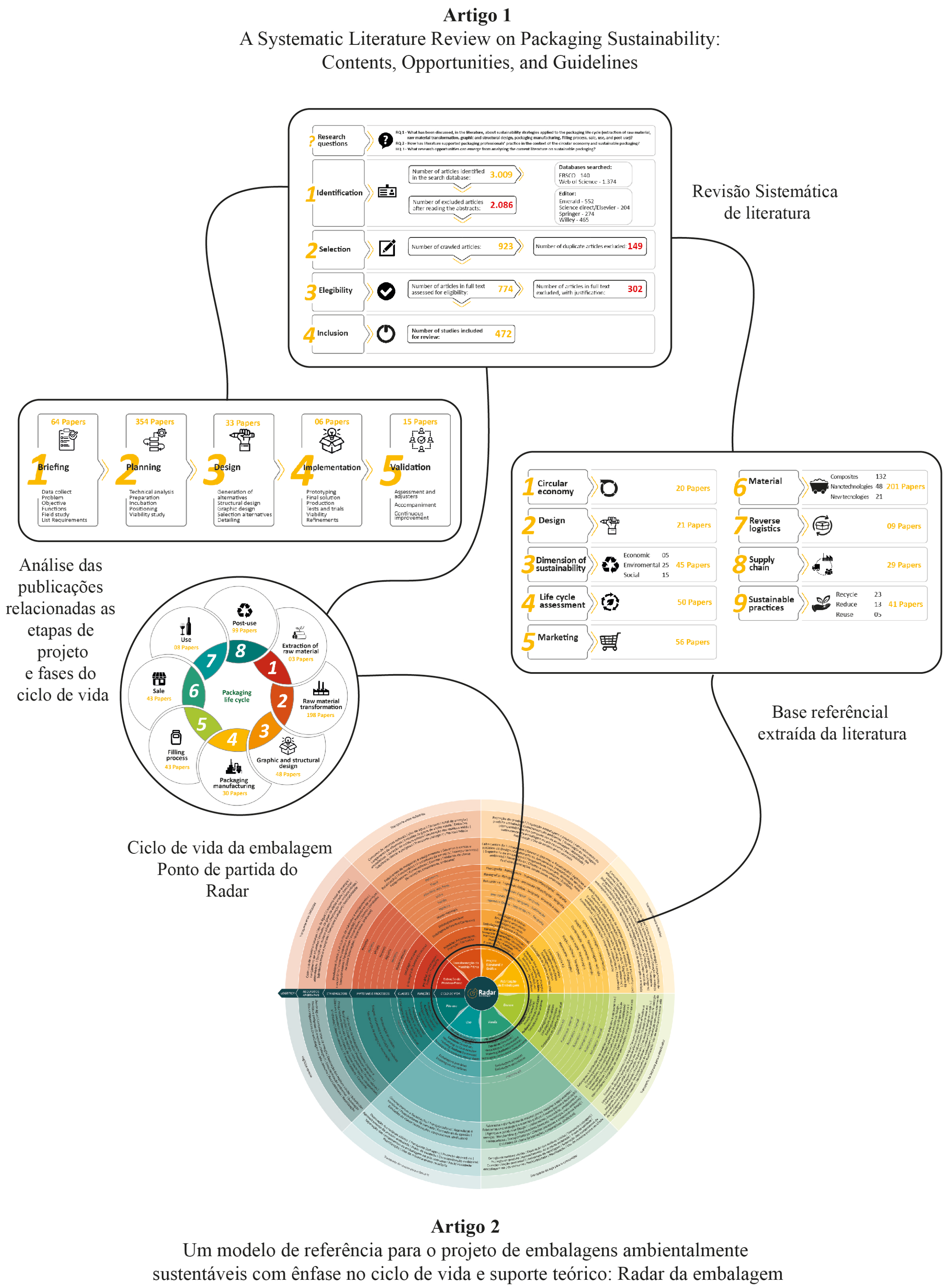
A Figura 14 mostra a integração entre os resultados do artigo 1 e artigo 2.

**Figura 14** – Integração entre artigo 1 e artigo 2




**Fonte:** O autor

# 3. ARTIGO 2 UM CORPO DE CONHECIMENTO PARA O PROJETO DE EMBALAGENS AMBIENTALMENTE SUSTENTÁVEIS COM ÊNFASE NO CICLO DE VIDA E SUPORTE TEÓRICO: RADAR DA EMBALAGEM

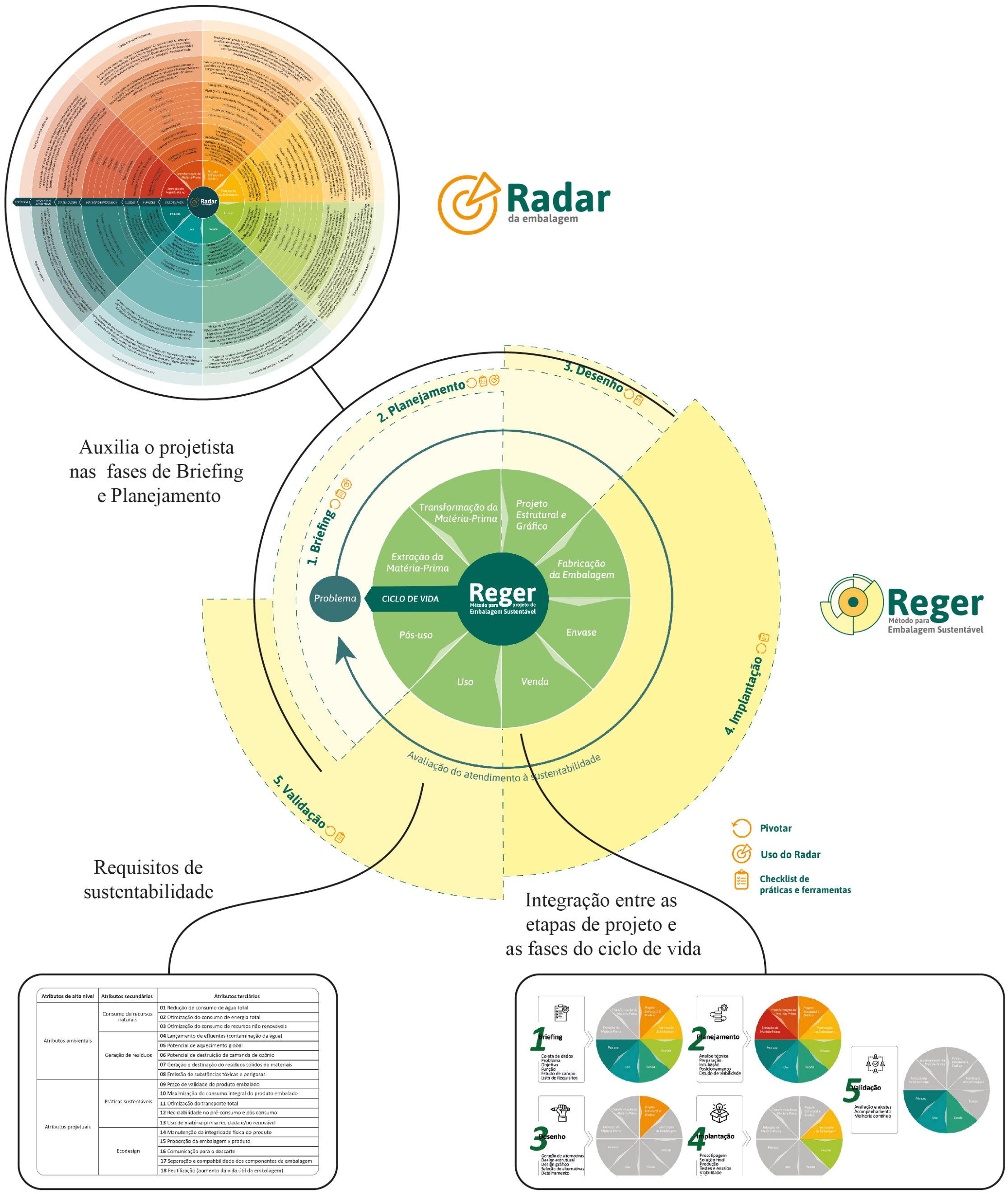
**Resumo**: A embalagem sustentável deve atender múltiplos critérios do contexto de aplicação e de cada fase do seu ciclo de vida. Os métodos de projeto de embalagens sustentáveis em sua maioria não explicitam diretrizes relativas ao ciclo de vida e conteúdos relevantes, em consequência disto, os projetistas acabam negligenciando informações críticas para a sustentabilidade desde a definição do escopo da embalagem. O objetivo neste artigo é propor um corpo de conhecimento que considere o arcabouço teórico próprio de cada etapa do ciclo de vida da embalagem, que ofereça uma perspectiva ao mesmo tempo simples e sistêmica e que sirva de diretriz para o projeto de embalagens sustentáveis. Para a construção do corpo de conhecimento utilizou-se a metodologia *Design Science Research*. O instrumento reúne objetivamente conhecimentos que estão dispersos na literatura acadêmica nas categorias: funções e classes das embalagens, materiais e processos, stakeholders, requisitos ambientais e logística. Tais conhecimentos foram contextualizados pelas oito etapas do ciclo de vida, desde a extração da matéria prima até o pós- uso. O corpo de conhecimento foi representado em formato circular, razão de ser denominado 'Radar da embalagem'. A natureza gráfica, no formato de *one page,* foi cuidadosamente desenhada para facilitar a leitura, consulta, percepção de interdependências entre conteúdos e visibilidade de todo o ciclo de vida. Como o corpo de conhecimento faz com que a perspectiva complexa e interdependências do ciclo de vida se tornem tangíveis para os membros da equipe, revelando que as ideias e decisões de projeto podem ser consequenciais. Recomenda-se o uso pelo time nas etapas de briefing e planejamento para trazer visibilidade sobre o sistema da embalagem, produzindo alinhamento, engajamento e maior qualidade à tomada de decisão que gere menores impactos ambientais. Sob o ponto de vista prático, o radar se converte em parte integrante de um método especialista para embalagens sustentáveis para profissionais do mercado ou para fins de formação profissional.

**Palavras-chaves:** Design de embalagem; Sustentabilidade; Ciclo de vida; Corpo de conhecimento.

A Figura 28 mostra a integração entre os resultados do artigo 2 e artigo 3.

**Figura 28** – Integração entre artigo 2 e artigo 3

**Artigo 2**
Um modelo de referência para o projeto de embalagens ambientalmente sustentáveis com ênfase no ciclo de vida e suporte teórico: Radar da embalagem




**Artigo 3**
REGER: Um método sistêmico para o desenvolvimento e avaliação de embalagens ambientalmente sustentáveis

Fonte: O autor

# 4. ARTIGO 3 REGER: Um método sistêmico para o desenvolvimento e avaliação de embalagens ambientalmente sustentáveis

**Resumo**: A embalagem é parte integrante do produto e exerce um papel relevante dentro da cadeia de suprimentos. Em seu fim de vida, a embalagem pode tornar-se um resíduo se não for descartada corretamente. A integração e avaliação dos requisitos de sustentabilidade em todo o ciclo de vida é um elemento chave, nem sempre tratado nos métodos de projeto de embalagens. Assim, a questão que norteia esta pesquisa é como viabilizar que o projeto de uma embalagem integre os requisitos da sustentabilidade e permita a verificação do seu cumprimento ao longo de todo o seu ciclo de vida? O objetivo é propor um método sistêmico para projetar embalagens, integrando os requisitos da sustentabilidade e a verificação do seu cumprimento ao longo do ciclo de vida. Utilizou-se como base para a construção do método a abordagem *Design Science Research*. O método de projeto de embalagens sustentáveis, denominado REGER, foi concebido a partir da integração das etapas de projeto com as fases do ciclo de vida. Seu ponto de partida traz à tona a real necessidade de uso de uma embalagem, incentivando o projetista a refletir sobre os objetivos do projeto. O método proposto integra as etapas de projeto com as fases do ciclo de vida, trazendo uma visão sistêmica. A incorporação da ferramenta Radar da Embalagem à estrutura do método enrobusteceu as etapas de briefing e planejamento, com o propósito de oferecer suporte às decisões do escopo de uma embalagem ambientalmente sustentável. O método contempla ainda ferramentas sugeridas para as etapas de desenho, implementação e validação do projeto de embalagem sustentável. Visando a verificação do grau de desempenho ambiental da embalagem foram identificados requisitos e especificações-meta aplicáveis a todo o seu ciclo de vida. Como limitação, o desenvolvimento de uma escala quantitativa de avaliação de desempenho foi deixado para pesquisas futuras. Testes preliminares do método proposto foram realizados empregando o projeto incremental de uma embalagem para alimentos. Embora a aplicação seja considerada como preliminar, o projeto de embalagem fruto do teste recebeu troféu no 15º prêmio de excelência gráfica, na categoria inovação tecnológica, devido à perspectiva sistêmica que assumiu, atendendo as demandas de stakeholders da cadeia.

**Palavras-chaves:** Design de embalagem; Método de projeto; Sustentabilidade; sistêmico; desempenho ambiental

# 5. CONSIDERAÇÕES FINAIS

Neste capítulo são apresentadas e discutidas as principais contribuições teóricas e práticas desta tese, bem como as limitações da pesquisa e as sugestões para futuros trabalhos na área de embalagem em um contexto de sustentabilidade.

Esta pesquisa encontra-se na temática de métodos para projeto de embalagens sustentáveis. Sua principal contribuição prática foi o desenvolvimento de um conjunto de métodos (Radar da embalagem e Método REGER) para o desenvolvimento de embalagens sustentáveis sob a perspectiva sistêmica, inserida em um ambiente de complexidade. Uma contribuição paralela desta tese foi o desenvolvimento de um arcabouço teórico sobre a temática da embalagem e sustentabilidade.

## 5.1 PRINCIPAIS CONTRIBUIÇÕES

A Revisão Sistemática de literatura, apresentada no capítulo 2 do presente estudo, apresenta uma referência preliminar sobre embalagens no contexto da sustentabilidade, propõe *insights* e identifica oportunidades de pesquisa. A literatura acadêmica compreende algumas revisões sistemáticas da literatura sobre a embalagem. No entanto, se reduziu o número de palavras-chaves na busca para recuperar o maior número de publicações sobre embalagem no contexto da sustentabilidade. O objetivo era cobrir 30 anos de investigação para se obter uma ampla perspectiva do que tem sido pesquisado até agora. A principal contribuição foi apresentar um repositório atualizado de informações para apoiar pesquisadores e profissionais de embalagens.

A análise da literatura revelou nove categorias de temas organizados em quatro clusters. O primeiro cluster incluiu as dimensões da sustentabilidade (ambiental, econômica e social) com (9,5%) das publicações, materiais (42,6%) e marketing (11,9%), publicados a partir da década de 1990. O segundo cluster incluiu artigos publicados dez anos mais tarde (2000) foram encontradas publicações sobre avaliação do ciclo de vida (10,6%), cadeia de suprimentos (6,1%) e práticas sustentáveis (reciclar, reduzir, reutilizar) com (8,7%). O terceiro cluster é o mais recente (2013 em diante), trouxe publicações sobre logística reversa (1,9%) e economia circular (4,2%), e o quarto cluster, design (4,5%) das publicações, foi bastante diferente de todos os outros clusters em suas características. O elevado número de artigos sobre o tema materiais, por um lado, tem demonstrado a forte preocupação dos pesquisadores em reduzir os danos ambientais das embalagens de alimentos e torná-las seguro para a saúde humana. Por outro lado, esses achados podem ser referências importantes para diferentes segmentos industriais em novas matérias-primas, nanotecnologia e embalagens inteligentes. Os conteúdos do repositório são dinâmicos, portanto, o projetista deverá se manter sempre atualizado. As categorias podem servir de referência para busca de informações que envolvem o projeto da embalagem sistêmica.

O corpo de conhecimento denominado Radar da embalagem, contempla categorias de conteúdos teóricos que fundamentam o projeto e desempenho de uma embalagem sob a perspectiva de seu ciclo de vida e, no formato que foi desenhado, oferece suporte técnico de forma simples, objetiva e holística sobre o complexo projeto de uma embalagem sustentável. O corpo de conhecimento contempla referencial teórico sobre os principais elementos que compõem um projeto de embalagem, são eles: ciclo de vida; funções da embalagem; classificação; materiais e processos de produção; stakeholders, requisitos ambientais e logística.

O Radar da embalagem contribui para a visualização destes contextos e conteúdos implícitos no projeto, auxiliando o projetista em vislumbrar e criar soluções apropriadas. Além disso, o corpo de conhecimento compila de forma gráfica interdependências entre conteúdos e fases do ciclo de vida, que auxiliam a nortear a tomada de decisão de projeto ainda nas fases iniciais. A rápida visualização facilita o entendimento do projetista em relação a sua demanda técnica criativa, podendo servir de instrumento para capacitação de pessoal ou instrumento pedagógico na área de projeto de embalagem.

Sugere-se o uso do Radar da embalagem no método REGER, através de ícones, nas etapas de (briefing e planejamento), auxiliando no levantamento de informações importantes sobre o projeto de embalagem sustentável. O ponto de partida do método REGER traz à tona a real necessidade de uso de uma embalagem, incentivando o projetista a refletir sobre os objetivos do projeto. A embalagem é importante para a circulação de bens de consumo no mundo, mas é fonte geradora de resíduo, se for possível evitá-la o impacto ambiental do produto será menor.

A representação gráfica do método REGER orienta o profissional a iniciar o projeto levantando informações relacionadas as etapas de pós-uso e extração da matéria-prima. Esta ação visa a tomada de decisão que minimize o impacto ambiental por todo o ciclo de vida. É importante entender o problema do resíduo antes de gerá-lo e buscar soluções com menor impacto ambiental. Recomenda-se visitar centros de reciclagem e entender quais são os desafios que dificultam o destino de embalagens no fim de vida, tais como tipo de materiais, formatos, descaracterização, separação, dentre outros e quais as oportunidades encontradas, como materiais compostáveis ou de fácil manejo na esteira de separação, por exemplo. Em relação a extração da matéria-prima, sugere-se uma reflexão sobre o uso de materiais antes de iniciar o projeto. Ponderar o uso de materiais reciclados; buscar novas soluções no mercado e na área acadêmica e evitar o uso se matérias-primas extraídas de fontes não renováveis.

Outro ponto relevante sobre o método apresentado é a integração das etapas de projeto com as fases do ciclo de vida, trazendo uma visão sistêmica e sustentável em um projeto de embalagem. Neste sentido, preocupou-se em evidenciar os aspectos relacionados a sustentabilidade em sua construção gráfica e informacional.

Propõem-se através de requisitos, a avaliação do atendimento à sustentabilidade durante todo o desenvolvimento do projeto, buscando garantir a redução do impacto ambiental em todo o processo. A estrutura do método apresentado permite sua aplicação para o desenvolvimento de uma simples caixa de embarque (embalagem terciária), ou até um projeto mais complexo, envolvendo a área da saúde, por exemplo.

## 5.2 LIMITAÇÕES

Embora entendamos que a questão de pesquisa e objetivo desta tese tenham sido alcançados, as seguintes limitações devem ser apontadas. A primeira, comentada na seção 1.6, delimitação do estudo, é a concepção do método especialista para embalagens. Apesar de convergir com o produto, esta integração (sistema produto embalagem) não foi aprofundada. Retomando a introdução, manter a integridade física do produto, principalmente a validade dos alimentos, contribui para preservar energia gasta na produção, transporte, armazenamento e cozimento, evitando desperdícios e minimizando impacto ambiental. Em síntese, a embalagem mais sustentável não é a de menor impacto ambiental, é a que minimiza o impacto da cadeia (INCPEN, 2005).

O caso apresentado implementou a avaliação da sustentabilidade em nível intermediário, compreendido em uma análise simples, utilizando as informações coletadas pelos envolvidos no projeto. Neste caso, os requisitos de sustentabilidade podem ser utilizados por estarem acessíveis aos projetistas, estes não dependem de dados mais profundos, como redução de consumo de água na cadeia, por exemplo. Em última instância, o nível intermediário analisa todas as diretrizes e aplica somente aquelas que forem factíveis ao escopo do projeto.

Os requisitos de sustentabilidade são uma lista dinâmica, ou seja, novos itens podem aparecer e ser incorporado, os projetistas podem atualizá-las a cada projeto ou através de pesquisas na literatura. Podem ser desenvolvidos métricas multivariadas e que levem em consideração outros aspectos ou através de indicadores que possam guiar a equipe durante o desenvolvimento.

Por fim, o método REGER foi testado em apenas um caso real, recomenda-se a aplicação do método e a avaliação da sustentabilidade em diferentes tipos de projetos para verificar a completude dos requisitos.

## 5.3 SUGESTÕES PARA PESQUISAS FUTURAS

Dentre os tópicos sugeridos para as pesquisas futuras abordados no decorrer dos três artigos, se destacam algumas oportunidades que podem ser desenvolvidas a partir desta tese.

i. Pesquisar em maior profundidade sobre a relação da embalagem com o produto (sistema produto embalagem) e seus impactos ambientais;
ii. Promover a integração entre as áreas acadêmica, pública e privada na busca de soluções sustentáveis para o sistema de embalagens;
iii. Ampliar os estudos sobre os elementos contidos em um projeto de embalagem, tais como, novos materiais, indústria 4.0 e gerenciamento de resíduos no pós-consumo;
iv. Integrar o Radar da embalagem e o método REGER à engenharia de requisitos;
v. Desenvolver o Radar do design de embalagens, aprofundando os elementos gráficos (visual) e glíficos (estrutural) de uma embalagem;
vi. Aprofundar os estudos referentes as ferramentas e processos criativos utilizados para o desenvolvimento de embalagens sustentáveis.
vii. Aproximar outras ferramentas da engenharia ao método proposto, tais como: *Lean canvas*, *Life-cycle analysis* (LCA), *Customer Value Chain* (CVCA), *Value constelation; Value proposition, Quality Function Deployment* (QFD), *Product Service System* (PSS) e *Functional Resonance Analysis Method* (FRAM), dentre outros.
viii. Incorporar ao método REGER os três princípios da economia circular, apresentado pela (Ellen Macarthur Foundation, 2022) são eles: Eliminar resíduos e poluição desde o princípio; manter produtos e materiais em uso e regenerar sistemas naturais;
ix. Os requisitos de sustentabilidade contemplaram a dimensão ambiental, recomenda-se como estudos futuros, a inclusão de atributos econômicos e sociais;
x. Encorajam-se pesquisadores, professores e projetistas envolvidos em embalagens para aplicarem o método em outros projetos, testar os requisitos de sustentabilidade proposto e apontar melhorias.

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